Lithium Battery Risk Mitigation Guidance for Operators

2nd Edition

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Foreword

In April 1945, 57 airlines from 31 countries gathered in Havana, Cuba to found the International Air Transport Association (IATA). Global standards, partnerships and collaboration were the driving force behind the creation of IATA – elements that are just as important today as they were seven decades ago. A focus on safety, for example, transcends commercial interest. Everybody benefits from a safer industry.

Commercial aviation has become ever more accessible, attracting billions of passengers each year, all of whom rely on the industry to get them to their destination **safely**. Their safe passage is due to the tireless efforts of industry stakeholders, both public and private. Working together, we have made aviation the safest form of long-distance travel ever invented.

Recent events remind us that emerging technologies have the potential to introduce new challenges to this impressive safety record. The proliferation of lithium batteries is one such challenge; it is estimated that each year, upwards of one billion lithium batteries are transported by air as mail, cargo or in passenger/crew baggage. Lithium batteries have become so common that just about everyone on board an aircraft carries one or more on their person.

Lithium batteries have become the preferred energy source to power a wide variety of consumer goods ranging from mobile phones, laptops and tablets to educational and recreational gadgets, right up to e-bikes and passenger vehicles. Lithium batteries are also used to power life-saving medical devices that must be shipped in a time-sensitive manner by air.

Though widely used, much of the general public – even public traveling by air – are not aware that lithium batteries are dangerous goods and can pose a safety risk if not manufactured, prepared, packaged, tested and transported in accordance with the transport regulations. To help educate and facilitate compliance with the various requirements, IATA has developed guidance information for shippers, freight forwarders, ground handlers, airlines and passengers.

IATA has developed this second edition of the Lithium Battery Guidance for Operators in collaboration with various industry bodies, including leading industry groups specialized in the handling of Dangerous Goods. Intended for airlines, this document provides strategies to reduce the risk associated with the carriage of lithium batteries by air.

The document is copyright-free, allowing download and onward distribution to all interested parties.

I wish to thank the ICAO Dangerous Goods Panel (DGP), IATA Dangerous Goods Board (DGB), IATA Cargo Department, IATA Safety Group (SG), The Dangerous Goods Office Limited and IATA Safety for their cooperation and expertise which was essential for the creation of this document.

Gilberto LOPEZ MEYER
Senior Vice President
Safety and Flight Operations

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Introduction

Scope

This guide is designed to outline potential strategies airlines may wish to consider to reduce the risks associated with the transport of lithium batteries.

After much discussion and review of information from all stakeholders, on January 27th, 2016, the ICAO Air Navigation Commission (ANC) concluded that the risks associated with the carriage of lithium-ion batteries as cargo on passenger aircraft are not adequately controlled. As such, the ANC recommended to the ICAO Council that lithium-ion batteries packaged on their own (UN 3480), be forbidden for transport as cargo on passenger aircraft, until adequate controls to reduce the safety risks are put in place.

The council adopted this recommendation and in February 2016, issued Addendum 4 to the 2015-2016 edition of the Technical Instructions, which prohibited the carriage of lithium ion batteries, UN 3480, on passenger aircraft with effect from 1 April 2016. This prohibition does not impact lithium-ion batteries packaged in, or with, equipment (UN 3481).

The Commission has identified the need for a timely and clear work plan to develop the necessary controls to negate the need for this prohibition. Controls identified include performance-based packaging standards, risk assessment provisions and associated guidance material.

The strategies outlined in this guide are primarily directed at an airline's internal processes and procedures, although there are strategies for engaging with other entities in the supply chain, such as manufacturers of lithium batteries, shippers, freight forwarders and the travelling public.

It should be noted that IATA has developed comprehensive guidance information for shippers, freight forwarders, ground handlers, airlines and passengers which may be found on the following web page:

http://www.iata.org/whatwedo/cargo/dgr/Pages/lithium-batteries.aspx

Background

Lithium batteries power many portable electronic devices (PEDs), such as laptop computers, tablets and mobile phones; they have become the battery of choice due to their ability to power such devices for hours or even days. Very stringent international requirements apply to their manufacture, testing and transport. Providing these standards are complied with, lithium batteries are very safe. The legitimate lithium battery industry (i.e. those companies adhering to the international rules) has an outstanding safety record since these batteries started to be shipped by air in the mid-1970s.

A lithium battery is two or more "cells" that are connected together, for example in a laptop battery. Some devices, such as mobile phones and watches, are powered by one or more individual lithium cells. For simplicity, the terms battery/batteries is used throughout this document, but any reference will apply equally to cells.

Lithium batteries are grouped into two categories based on the battery chemistry:

1. Lithium metal batteries

Sometimes referred to as "primary" batteries, lithium metal batteries are typically non-rechargeable and used in long-life applications such as watches, calculators and emergency locator beacons. Examples include:

AA cells

C32032 button cell

CR123A cells

Figure 1. Examples of lithium metal batteries

The term "lithium metal" encompasses lithium alloy batteries and includes those containing sulfuryl chloride and thionyl chloride.

2. Lithium ion batteries

Sometimes referred to as "secondary" batteries, lithium ion batteries are rechargeable and used in consumer electronics such as mobile phones and laptop computers, and in larger applications such as e-bikes and motor vehicles.

Mobile phone battery

Laptop battery

E-bike battery

Figure 2. Examples of lithium ion batteries

The term "lithium ion" includes lithium polymer and lithium iron phosphate batteries.

The Issue

Because of the huge, worldwide demand for lithium batteries, billions are shipped annually as cargo on both passenger and cargo aircraft. With the prohibition now in place, transport is expected to shift more towards the cargo arena. Volumes are expected to increase substantially over the coming years, with batteries becoming smaller and even more powerful. The IATA Dangerous Goods Board previously estimated that, on some routes, lithium batteries were present in some 25% of cargo shipments. However, this estimate only takes into account those lithium batteries that are known to be transported (i.e. those that have been declared to the operator). It does not include undeclared shipments, the exact volume of which is unknown. Judging from the incidents that are known to have occurred, the issue of undeclared shipments is clearly quite widespread.

Lithium batteries have become such a common, everyday item that they have been taken for granted by consumers, with little thought given to the precautions that need to be taken to ensure lithium batteries do not pose a hazard in air transport. This is an issue in passenger baggage (see Chapter 6 of this guide), but even more so in air cargo. Experience has shown that there are shippers who, either deliberately or through ignorance, do not follow the requirements. Consequently, incidents involving lithium batteries catching fire on board aircraft have occurred. It is not always possible to determine the cause of such incidents, but where a cause has been determined, they would appear to be almost invariably due to non-compliance with the requirements.

Figure 3. **Fire damage to a package of incorrectly packed lithium metal button cells, which occurred after unloading**

There was a great deal of publicity surrounding the loss of three cargo aircraft due to onboard fires:

- February 7, 2006: DC-8, Philadelphia – aircraft landed safely, but was destroyed by fire which had started in the descent.

- September 3, 2010: Boeing 747, Dubai – the aircraft crashed during an attempt to return to Dubai due to a severe inflight fire; both crewmembers were killed.
- July 27, 2011: Boeing 747, 130 km west of Jeju Airport, South Korea – the aircraft crashed into the sea following a severe inflight fire; both crewmembers were killed.

It is known that all three aircraft were carrying lithium batteries as cargo, some of which on the Boeing 747 were subsequently determined to have not complied with the regulatory requirements. However, the degree to which the lithium batteries were involved in these incidents (i.e. whether they were the cause or aggravated the fire) could not be determined.

There is also the problem of low quality and counterfeit/fake (i.e. purporting to be genuine) batteries that have been the cause of incidents. It is often very difficult to distinguish fake batteries from the genuine article, as can be seen in the two examples below:

The genuine article *The fake*

Figure 4. Example of a counterfeit lithium battery

Airmail

The safety concerns are not restricted to baggage and cargo. Mail is carried extensively onboard passenger aircraft, both internationally and on relatively short domestic flights. Lithium batteries, whether on their own or packed with equipment, are not permitted in airmail. Nevertheless, numerous web sites advertise lithium batteries for sale with delivery by airmail as an option. Couple this with the fact that a number of such batteries may not comply with the regulatory requirements, it is not surprising that there have been a number of incidents involving lithium batteries in airmail.

Figure 5. A non-compliant laptop battery ordered online and sent by airmail, which caught fire shortly after being unloaded from a passenger aircraft at London Heathrow Airport

There are provisions for lithium batteries, when contained in equipment, to be sent by airmail providing the National Aviation Authority (NAA) has approved the Designated Postal Operator (DPO) of the State (country) in which the airmail is offered for carriage. However, in many parts of the world there is a lack of communication between the DPO and NAA and so the approval system may be absent. There may also be other problems, such as:

- The NAA may not have authority over airmail or the DPO, and is therefore unable to exercise the necessary oversight.
- The postal authority may not be subject to civil aviation regulations.

Consequently, it is recommended that operators carrying airmail should liaise closely with the NAA and DPO in their State.

International Requirements

Lithium batteries are defined as dangerous goods by the United Nations, which specifies the very stringent manufacturing and testing requirements the batteries must meet. Specific requirements to ensure they can be carried safely by air in both cargo and baggage are determined by the International Civil Aviation Organization (ICAO) and these are then reflected in IATA's Dangerous Goods Regulations.

The requirements differ for carriage of lithium batteries as cargo depending on the chemistry of the battery (i.e. lithium metal or lithium ion), and whether the batteries are shipped on their own or packed with or contained in equipment. Generally, lithium batteries are subject to all of the ICAO/IATA requirements for dangerous goods as cargo (e.g. marking, labelling, declaration and training). However, small quantities of small lithium batteries are excepted from many of the requirements, e.g. Shipper's Declaration, dangerous goods acceptance or inclusion on the written information to the pilot-in-command (NOTOC), but all batteries are subject to the testing requirements of the United Nations. Furthermore, even when small enough to benefit from the exceptions mentioned here, lithium batteries shipped on their own or with equipment (and when more than two batteries or four cells are contained in equipment in a package), the packages are required to be labelled with the lithium battery handling label and the consignment must be accompanied by an additional document that provides safety related information.

Figure 6. The Lithium Battery Handling Label

The requirements applicable to lithium batteries have evolved over recent years to address safety concerns by reducing the quantity of lithium batteries permitted per package as well as enhancing hazard communication, including requiring more lithium battery shipments to be notified to the pilot-in-command.

There remain however, a number of systemic problems with lithium batteries. Their ubiquitous nature means that people who are completely unaware of the dangerous goods regulations and the requirements for lithium batteries are shipping them as cargo and in mail. Worse still, unscrupulous individuals are prepared to flout the requirements and put passengers and crew at risk. Many passengers are similarly oblivious to the potential hazards of lithium batteries. The result is that there are safety risks from lithium batteries in baggage, cargo and mail. This guide has been produced to assist operators in determining their strategies for mitigating these risks.

Guide Structure

This guide is organized as follows:

Chapter 1: Risk Assessment/Analysis

Operators have an obligation to apply the principles of risk management to all activities where there is a perceived risk. This chapter looks at how this can be done in the context of lithium batteries.

Chapter 2: Outreach and Awareness

Passengers and those involved in the shipment and transport of lithium batteries must be made aware of the restrictions that apply, but this can be very difficult to achieve. This chapter looks at what initiatives to consider to raise awareness of the subject.

Chapter 3: Cargo Acceptance and Handling

In addition to the actions mandated by the international transport requirements of ICAO and IATA, operators may wish to consider additional measures that can contribute to mitigating the risk represented by the carriage of lithium batteries.

Chapter 4: Passenger/Crew Baggage

With the heavy reliance on lithium batteries around the world, passengers will inevitably carry them in their checked and carry-on baggage, and on their person. This chapter looks at which lithium batteries are permitted and where they must be carried.

Chapter 5: Training and Procedures

This chapter focuses on training for cabin and flight crew, and reflects the material contained in the ICAO Emergency Response Guidance for Aircraft Incidents Involving Dangerous Goods (known as the 'red book').

Chapter 6: Current Mitigations and Future Developments

Recent cargo fires on freighter aircraft have highlighted the vulnerability of the main deck cargo compartment to fires. As a result, there are a number of new technologies being pursued in the industry to address this area of vulnerability.

Chapter 7: Further Information

Chapter 1: Risk Assessment/Analysis

1.1 Introduction

It is strongly recommended that operators conduct a risk assessment to identify all risks relating to the transport and carriage of lithium batteries as cargo on passenger and cargo aircraft as well as in passenger and crew checked and carry-on baggage. Risk management seeks to be proactive by identifying hazards and assessing risks before they become events. The objective of risk management is to minimize operational risk and maximize business opportunities. It may also be used to ensure regulatory compliance. Therefore, all activities where there is a perceived or potential risk should come under the scrutiny of the basic principles of risk management, and this certainly applies to the carriage of lithium batteries. However, risk assessments should not be limited to scenarios where it is known lithium batteries are present; the operator that has a policy of not carrying dangerous goods as cargo is just as vulnerable to carrying undeclared lithium batteries as an operator that carries dangerous goods.

The risk assessment should be performed by a team of senior-level representatives from key areas, such as Cargo, Safety and Flight Operations (preferably personnel with appropriate knowledge on the subject). This risk assessment needs to consider the potential risk looking at all the points of entry for cargo, mail and passenger baggage, as applicable, and the types of aircraft being operated (passenger and/or cargo). Based on the risk assessment, an identification of potential risk mitigation strategies should follow.

1.2 ICAO Safety Management Manual Risk Model

The ICAO Safety Management Manual (Doc 9859) contains comprehensive guidance for both industry and regulators on the subject of risk assessment. This guide will not reproduce large parts in this document, but it is useful to consider the basic elements of safety risk mitigation as it applies to lithium batteries.

A risk assessment seeks to identify potential hazards (what could happen) and consider the likelihood of them happening. This will give us the "risk" and by identifying these risks, it is possible to determine mitigation strategies to reduce them to an acceptable level. As with any risk assessment, the starting point is to determine the potential severity, or the "ultimate consequence" of a lithium battery catching fire. ICAO provides the following "Severity Table":

Table 1. Severity Table

Level	Descriptor	Severity Description
1	Insignificant	No significance to aircraft related operational safety.
2	Minor	Degrade or affect normal aircraft operational procedures or performance.
3	Moderate	Partial loss of significant/ major aircraft systems or result in abnormal F/Ops procedure application.

Level	Descriptor	Severity Description
4	Major	Complete failure of significant/ major aircraft systems or result in emergency F/Ops procedure application.
5	Catastrophic	Loss of aircraft or lives.

The next step is to assign a degree of likelihood based on events related to the transport of lithium batteries, in accordance with the following table:

Table 2. Likelihood Table

Level	Descriptor	Likelihood Description
A	Certain/frequent	Is expected to occur in most circumstances
B	Likely/occasional	Will probably occur at some time
C	Possible/remote	Might occur at some time
D	Unlikely/improbable	Could occur at some time
E	Exceptional	May occur only in exceptional circumstances

Combining the severity by the likelihood (e.g. 4 x E = 4E), gives us a "Risk Index" according to the following table:

Table 3. Risk Index Matrix (Severity × Likelihood)

Likelihood	Severity				
	1. Insignificant	2. Minor	3. Moderate	4. Major	5. Catastrophic
A. Certain/frequent	Moderate (1A)	Moderate (2A)	High (3A)	Extreme (4A)	Extreme (5A)
B. Likely/occasional	Low (1B)	Moderate (2B)	Moderate (3B)	High (4B)	Extreme (5B)
C. Possible/remote	Low (1C)	Low (2C)	Moderate (3C)	Moderate (4C)	High (5C)
D. Unlikely/improbable	Negligible (1D)	Low (2D)	Low (3D)	Moderate (4D)	Moderate (5D)
E. Exceptional	Negligible (1E)	Negligible (2E)	Low (3E)	Low (4E)	Moderate (5E)

The acceptability (tolerability) of the risk index must then be determined by using the following table:

Table 4. Risk Acceptability (Tolerability)

Risk Index	Tolerability	Action Required (customize as appropriate)
5A, 5B, 4A	Extreme Risk	STOP OPERATION OR PROCESS IMMEDIATELY. Unacceptable under the existing circumstances. Do not permit any operation until sufficient control measures have been implemented to reduce risk to an acceptable level. Top Management approval required.

Risk Index	Tolerability	Action Required (customize as appropriate)
5C, 4B, 3A	High Risk	CAUTION. Ensure that risk assessment has been satisfactorily completed and declared preventive controls are in place. Senior management approval of risk assessment before commencement of the operation or process.
1A, 2A, 2B, 3B, 3C, 4C, 4D, 5D, 5E	Moderate Risk	Perform or review risk mitigation as necessary. Departmental approval of risk assessment.
1B, 1C, 2C, 2D, 3D, 3E, 4E	Low Risk	Risk mitigation or review is optional.
1D, 1E, 2E	Negligible Risk	Acceptable as is. No risk mitigation required.

We can use these tables to conduct basic risk assessments with respect to lithium batteries, for example:

Example 1: *An operator of passenger aircraft within Europe wishes to risk assess the carriage of portable electronic devices (PEDs) in the cabin of their aircraft.*

Severity level – If a PED catches fire in the cabin, fire extinguishers will be readily available to cabin crew, who will have been trained in their use. Additionally, water, which is necessary to cool lithium batteries involved in an incident, will be at hand. Therefore, on the basis that an abnormal flight operations incident procedure would be applied (firefighting by cabin crew), with few other consequences, it may be appropriate to assign a severity level of 3 "moderate."

Likelihood – Given the propensity for portable electronic devices (PEDs) to be carried by passengers, it would be reasonable to assume that such an incident might occur at some time, and so the likelihood would be Level "C."

Therefore, the risk index would be severity (3) x likelihood (C) = **3C** "**Moderate**."

Example 2: *An operator of all-cargo aircraft wishes to risk asses the carriage of cargo from Hong Kong.*

Severity level – If cargo catches fire on the main deck of a cargo aircraft, this may become uncontrollable, resulting in a catastrophic situation. Therefore, the severity level should be 5 "catastrophic."

Likelihood – Experience has shown that undeclared, non-compliant lithium battery shipments originating from Hong Kong have been the cause of a number of incidents. Consequently, a fire in cargo is "possible" and likelihood should be Level "C."

Therefore, the risk index would be severity (5) x likelihood (C) = **5C "High"**

In the case of example 2, approval of the risk assessment is required if the operation is to continue. In both cases, a review of all risk mitigations in place should be undertaken and take account of:

Preventative controls – an action, process or other activity that prevent a hazard (in this case, a lithium battery catching fire) from escalating into an unsafe event (an aircraft fire) which could, in turn, result in the ultimate consequence, loss of the aircraft.

Escalation factors – factors (which may be latent) that could weaken the effectiveness of preventive controls.

Escalation controls – an action, process etc. that can prevent an escalation factor from inhibiting a preventive control.

In example 1 above, the following may apply:

Preventive control – prohibition of spare lithium batteries in checked baggage;

Escalation factor – passenger's ignorance of the requirement;

Escalation control – Operator has a robust process to ensure that all passengers are made aware of the requirement (e.g. by questioning at check-in).

In example 2 above, the following may apply:

Preventive control – lithium batteries must comply with very stringent requirements before being offered for carriage by air;

Escalation factor – shippers' inadvertent or willful non-compliance with the requirements;

Escalation control – Operator considers a system whereby lithium batteries will only be accepted from freight forwarders or shippers who have been vetted by the operator.

Despite preventive controls being in place, there is always the possibility that an unsafe event (in this case a lithium battery fire) can occur. Consequently, "recovery measures" must be considered (i.e. what can be done to prevent the unsafe event developing into the ultimate consequence, the loss of life or the aircraft). However, as with preventive controls, recovery measures can also be weakened by escalation factors that need to be controlled.

In example 1 above, the following may apply:

Recovery measure – Halon fire extinguishers and water available to cabin crew;

Escalation factor – fire extinguishers out of date, insufficient water carried;

Escalation control – robust process in place to ensure an aircraft cannot depart with out-of-date extinguisher or less than x liters of water.

In example 2 above, the following may apply:

Recovery measure – fire containment covers on all pallets or the use of fire-resistant containers;

Escalation factor – covers incorrectly applied, reducing their effectiveness;

Escalation control – covers only applied by trained personal and correct application verified by another qualified staff member.

The above elements can be more easily demonstrated with a "bow-tie" risk diagram, many of which have been produced by operators and regulators with respect to lithium batteries. A particular strength of the bow-tie concept is that it can readily identify where preventive controls or recovery measures are missing. For example, both large and small aircraft will have passengers with PEDs in carry-on baggage and both may experience incidents. However, large aircraft may have a variety of equipment to use in dealing with an incident (e.g. oven gloves), while small aircraft may not and operators should consider providing some level of equipment for cabin crew.

Determination of severity levels and likelihoods can be subjective, but is important that the safety culture of an operator embraces the concept that many activities associated with air transport, including the carriage of lithium batteries, involve risks that must be identified and mitigated to an acceptable level of tolerability.

1.3 Safety Risk Assessment (SRA)

Industry research has shown that bulk quantities of lithium batteries carried in cargo may represent higher risk. In support of the foregoing, IATA has created a guidance document to facilitate operators in conducting an SRA for the carriage of lithium batteries as cargo. It provides examples of factors that an operator should consider when completing this task. The document: Safety Risk Assessment (SRA) on the Aircraft Carriage of Lithium Batteries may be found at the following link:

http://www.iata.org/whatwedo/safety/Pages/index.aspx

It is essential that each Operator conduct their own SRA based on their own operational realities. The risks and their severity, the effectiveness of mitigations and controls, as well as the overall risk tolerance will be unique to each operation. As such, it is important to stress that this the SRA document is just guidance and should not be considered an actual assessment of an operation. In keeping with Safety Management System (SMS) requirements, it is important to note that any SRA completed should be regularly reviewed and updated accordingly. This to ensure that any operational or regulatory changes, as well as advances in industry technology, are reflected.

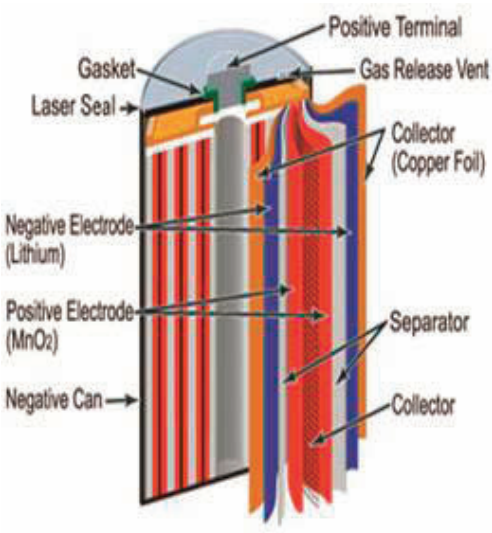
Chapter 2: Outreach and Awareness

Some basic information on lithium batteries

In order to understand the issues surrounding the carriage of lithium batteries, it is useful to have some basic understating of what they are and how they can fail.

A battery is a device that stores electrical energy and delivers that energy through a controlled electro-chemical reaction. A battery is usually composed of a series of cells that produce electricity- IATA defines a battery as two (2) or more cells that are connected together. Each cell has three essential components: the anode, the cathode and the electrolyte.

The anode donates electrons, and the cathode accepts them. The anode and cathode are separated by the electrolyte, which is a liquid or gel that conducts electricity. When the anode and cathode are connected, the anode undergoes a chemical reaction with the electrolyte in which it loses electrons, creating cations.



Lithium-ion batteries are vulnerable to a number of potential problems including overheating at the anode & oxygen production due to overcharging at the cathode. This has the potential to cause thermal runaway. There are some very stringent tests performed during the manufacture and testing of lithium-ion batteries to limit the charging voltage and allow for venting in the case of buildup of pressure.

Types of lithium batteries

There follows some information on some of the common types of batteries available.

Lithium Cobalt Oxide (LiCoO2)

The battery consists of a cobalt oxide cathode and a graphite carbon anode. The cathode has a layered structure and during discharge, lithium ions move from the anode to the cathode. The drawback of Li-cobalt is a relatively short life span, low thermal stability and limited load capabilities.

Thermal runaway	150°C (302°F). Full charge promotes thermal runaway
Applications	Mobile phones, tablets, laptops, cameras
Comments	Very high specific energy, limited specific power. Cobalt is expensive. Serves as Energy Cell. Market share has stabilized.

Lithium Manganese Oxide (LiMn2O4)

Most Li- manganese batteries "partner" with Lithium Nickel Manganese Cobalt Oxide (NMC). This improves the specific energy and prolongs life span. It is the chosen chemistry for most electric vehicles, such as the Nissan Leaf, Chevy Volt and BMW i3.

Thermal runaway	250°C (482°F) typical. High charge promotes thermal runaway
Applications	Power tools, medical devices, electric powertrains
Comments	High power but less capacity; safer than Li-cobalt; commonly mixed with NMC to improve performance.

Lithium Nickel Manganese Cobalt Oxide (LiNiMnCoO2 or NMC)

Similar to Li-manganese, these systems can be tailored to serve as Energy Cells or Power Cells. The cathode combination is typically one-third nickel, one-third manganese and one-third cobalt. NMC is the battery of choice for power tools, e-bikes and other electric powertrains

Thermal runaway	210°C (410°F) typical. High charge promotes thermal runaway
Applications	E-bikes, medical devices, EVs, industrial
Comments	Provides high capacity and high power. Serves as Hybrid Cell. Favorite chemistry for many uses.

Lithium Iron Phosphate (LiFePO4)

Li-phosphate offers excellent performance made possible by incorporating nano-scale phosphate cathode material. Key benefits include a high current rating, long cycle life, good thermal stability and enhanced safety and tolerance if abused.

Thermal runaway	270°C (518°F) Very safe battery even if fully charged
Applications	Portable and stationary needing high load currents and endurance
Comments	One of safest Li-Ions. Used for special markets. Elevated self-discharge.

Lithium Nickel Cobalt Aluminium Oxide- LiNiCoAlO2

Lithium Nickel Cobalt Aluminium Oxide battery, or NCA, has been around since 1999 for special applications Elon Musk choose NCA for the Tesla EV's. Issue with safety is well publicized.

Thermal runaway	150°C (302°F) typical, High charge promotes thermal runaway
Applications	Medical devices, industrial, electric powertrain (Tesla)
Comments	Shares similarities with Li-cobalt. Serves as Energy Cell.

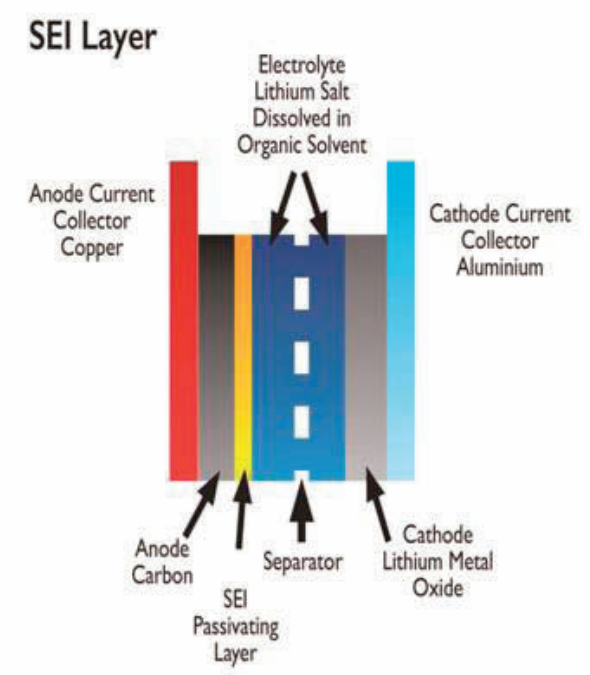
Lithium Titanate (Li4Ti5O12)

Li- titanate replaces the graphite in the anode. The cathode is graphite and resembles the architecture of a typical lithium-metal battery. Li-titanate is safe and has excellent low-temperature discharge characteristics. Typical uses are electric powertrains and UPS.

Thermal runaway	One of safest Li-ion batteries
Applications	UPS, electric powertrain (Mitsubishi i-MiEV, Honda Fit EV)
Comments	Long life, fast charge. Among safest Li-ion batteries.

Thermal Runaway

Thermal runaway is the term used to describe the overheating and failure of lithium batteries. It is this failure mode that causes the potential for on-board fires and why they are classed as dangerous goods. In the event of thermal runaway the anode breaks down to liberate methane and ethane gas. As the temperature continues to rise the cathode then breaks down releasing oxygen and therefore everything necessary for a fire. When the plastic casing ignites this will generally provide the ignition for a high temperature fire to ensue as each cell of the battery over heats.



The above information on lithium batteries was taken from a presentation by Michael Moselely of Dupree Chemicals

While there may be differing opinions with respect to how best to ensure lithium battery safety, all parties agree that effective outreach and awareness are key elements. With the advent of the Internet and social media, there are now more effective ways than ever of reaching passengers, shippers, etc. Furthermore, engagement with civil aviation authorities creates possibilities for outreach that would be difficult for an operator to achieve in isolation (e.g. regional seminars, advertising campaigns, etc.). This has the additional benefit of imparting information to civil aviation authorities that may not be as aware of the requirements as others. Enforcement by civil aviation authorities is also a key component to ensuring lithium battery safety.

Below are examples of outreach methods; some may be possible for an operator to implement alone, while others may require or benefit from the involvement of other parties such as civil aviation authorities, airport authorities, etc.:

Engagement with Freight Forwarders

Freight forwarders are an important interface between shippers and operators, but are largely unregulated. Engagement with freight forwarders, including advising them of the consequences of failure to comply with the requirements, can be very beneficial.

Engagement with Battery Manufacturers

One of the most frequent causes of battery incidents is the failure to protect against short circuit. Battery manufacturers are in the best position to educate purchasers by providing information on and in their packaging.

Engagement with Designated Postal Operators

Experience has shown that there is a great deal of ignorance among the public about what can and, more importantly, cannot be sent in the mail. ICAO requires that the appropriate civil aviation authority approve the procedures of Designated Postal Operators (DPOs) to control the introduction of dangerous goods into the mail. Therefore, it may be beneficial for operators and DPOs to work together in developing awareness strategies.

Warning Notices

Notices must be displayed at check-in desks at airports, warning passengers of the type of dangerous goods they must not carry. This is not ideal, since any warning at an airport is at a very late stage in the passenger's journey. Furthermore, warning notices are often generic in nature and experience has shown that passengers often do not even see them. Even if they do, they may be reluctant to empty the contents of their baggage in the very public area of an airport terminal.

Figure 2.1. Example warning notice aimed at passengers produced by the Civil Aviation Safety Authority of Australia (see http://shop.casa.gov.au/products/dangerous-goods-lithium-batteries-poster-a2)

Despite these limitations, warning notices have a role to play in raising awareness. Operators should consider specific warnings at airports where there are known problems, such as the prevalence of counterfeit and low-quality lithium batteries available to purchase at street markets. At such airports, warning notices may

actually be more effective in the arrivals baggage reclaim area to warn passengers before they have an opportunity to purchase the batteries.

Notices aimed at shippers have also been produced, but it is rare for shippers to offer items directly to operators. Consequently, such notices are best placed in the premises of freight forwarders or express courier companies where they are more likely to be seen by shippers.

Web Sites

It is important to warn passengers about the restrictions that apply to baggage at the earliest opportunity, ideally before they leave home. There are requirements that on-line ticket purchases can only be completed once information about dangerous goods has been displayed and an acknowledgement made that this information has been understood. Similar requirements apply to online check-in. These requirements are not foolproof, as the person purchasing the ticket or checking in may not necessarily be the person travelling or may click that they have read information without actually reading it. Nevertheless, this information should cover specific information about lithium batteries.

Beyond these requirements, web sites present other excellent opportunities to educate passengers on the limitations regarding dangerous goods in baggage, including the use of video.

Leaflets

Leaflets advising of the requirements in both baggage and cargo can be distributed at airport check-in areas, travel agents, freight forwarders, etc. These can be in paper or electronic format.

Arrival Videos

At the end of a flight, passengers may be shown a video about the city they are visiting. This provides a unique opportunity to inform a "captive" audience about the perils of purchasing cheap lithium batteries from market stalls, if that is relevant to the destination.

Inflight Magazines

Although too late to prevent batteries from being carried in manners that do not comply with requirements, an article in an inflight magazine may help passengers be more careful when packing their baggage on a subsequent flight.

Training

As the first point of contact between a passenger or shipper and the operator, it is important that sales and reservations staff be adequately trained concerning the requirements for the correct carriage of lithium batteries by air.

Other Publicity Material

Key fobs, drinks coasters, bookmarks and baggage tags have all been used to provide flight safety information.

Figure 2.2. Baggage tag produced by the Civil Aviation Safety Authority of Australia

IATA Passenger Information Pamphlets

IATA has developed the following lithium battery outreach and awareness products:

Figure 2.3. Example of a warning notice aimed at shippers, produced by IATA (see http://www.iata.org/whatwedo/cargo/dgr/Pages/lithium-batteries.aspx)

Figure 2.4. Passenger outreach, produced by IATA (see http://www.iata.org/whatwedo/cargo/dgr/Pages/lithium-batteries.aspx)

Display Cabinets

Display cabinets may be more eye-catching than warning notices and could contain examples of poor quality and counterfeit batteries, as well as examples of how to protect legitimate batteries against short circuit.

Figure 2.5. Display cabinet at an airport

Transit Vehicles

Buses and trains used to transfer passengers between airport terminals often have the ability to display safety related information, including videos.

Airport Magazines

Airports are increasingly producing their own magazines and often feature articles relevant to passengers.

Recreational Press

Magazines produced for specific recreational activities involving lithium batteries (e.g. radio-controlled models) may publish articles provided by operators. Such magazines are guaranteed to reach the relevant audience.

Newspapers

Newspapers have the potential to be read by a very wide audience, but can be very expensive.

TV and Radio

TV and radio campaigns have the potential to reach a very wide audience and, if used as part of a wider campaign, can be very effective.

Story Lines

Many millions of people watch popular TV shows and movies. Producers are sometimes amenable to including a story line with a public interest message. For example, a character could be seen being told not to put a battery in their checked baggage.

Seminars

Apart from the obvious benefit of providing learning opportunities, seminars have the ability to bring together many interested parties who may not normally come into contact with one another, thus facilitating an understanding of each other's perspectives.

Trade Press

In many parts of the world, magazines and newspapers are produced for specific industry audiences (e.g. freight forwarders, shippers, travel agents, etc.).

Schools

In some parts of the world, it has been possible to cooperate with education authorities to include a brief lesson for students who are shortly to leave school on what can and cannot be carried in baggage. As well as educating the students, this information is likely to be passed on to parents, friends, etc.

Social Media

Travelers may "follow" an operator on Twitter, Facebook, LinkedIn, etc.

2.1 Lithium Batteries as Cargo

Background

Following discussions at the ICAO Dangerous Goods Panel (DGP) over the 2012-2013 biennium, and a meeting of the DGP specifically on lithium metal batteries in April 2014, the DGP provided recommendations that led to ICAO prohibiting the carriage of lithium metal batteries as cargo on passenger aircraft. This decision came into effect as of 1 January 2015.

Allowance was made for lithium metal batteries shipped on a passenger aircraft under an exemption from the Technical Instructions in accordance with Special Provision A201.

The prohibition on the carriage of lithium metal batteries on passenger aircraft only applies to lithium metal batteries when shipped by themselves (PI 968 Section IA, IB & II). The prohibition does not apply to lithium metal batteries packed with equipment or lithium ion batteries contained in equipment, UN 3481, Packing Instruction 966 and Packing Instruction 967 respectively. (PI 969) or contained in equipment (PI 970).

Over the 2014-2015 biennium, the ICAO DGP focused discussions on the carriage of lithium ion batteries, primarily on passenger aircraft. Specifically around concerns that high density shipments of lithium batteries, even if packed and transported in accordance with the existing regulations, could originate or contribute to the development of a cargo fire that may exceed the limited capabilities of cargo compartment fire protection systems.

Subsequently, Airbus and Boeing released notices to their customers warning of the potential for a fire involving high density shipments of lithium-ion batteries that may exceed the capability of aircraft cargo

compartment fire protection / suppression systems. They further recommended that high density shipments of lithium ion batteries/cells not be allowed as cargo on passenger aircraft until safer methods of shipping were developed, and that operators conduct a safety risk assessment before accepting to carry lithium batteries as cargo. Separately, IFALPA and ICCAIA also recommended that appropriate requirements be established to transport lithium metal batteries/cells as cargo in freighter aircraft

The Panel considered a number of proposals to revise the provisions applicable to carriage of lithium batteries. The result of these discussions led to a DGP proposal for ICAO to introduce a requirement for lithium-ion batteries, under UN 3480, PI 965, Section IA and IB to be shipped at a state of charge (SoC) not exceeding 30% of their rated capacity. This applies to all lithium ion batteries when shipped by themselves and applies to both passenger and cargo aircraft. Shipment of cells or batteries at a SoC of more than 30% may only be transported with the approval of the State of Origin and the State of the Operator under the written conditions established by those authorities.

Note: more information on this may be found at:
https://www.iata.org/whatwedo/cargo/dgr/Documents/lithium-battery-guidance-document-2016-en.pdf.

At 30% SoC, the FAA Technical Center demonstrated that the majority of lithium ion battery chemistries used in consumer applications will not propagate in the event of a fire involving one cell or battery in a package. As a result, the DGP also proposed a significant restriction on the use of Section II of packing instruction 965, which applies to the small lithium ion batteries not exceeding 100 Wh. Currently shippers are restricted to having no more than 8 lithium ion cells or 2 lithium ion batteries per package, but there is no restriction on the number of individual packages, or the ability of a shipper to pack multiple packages into an overpack (an accumulation of packages into a larger box for the purpose of ease of handling). The DGP proposal was to limit a shipper to just one package of Section II in any consignment and forbid the use of overpacks.

The final changes for lithium batteries, effective 1 April 2016, are as follows:

1. UN 3480, PI 965, Section IA and IB. Lithium ion cells and batteries must be offered for transport at a state of charge (SoC) not exceeding 30% of their rated design capacity.

   Cells and/or batteries at a SoC of greater than 30% may only be shipped with the approval of the State of Origin and the State of the Operator under the written conditions established by those authorities.

   Note: Guidance and methodology for determining the rated capacity can be found in the UN Manual of Tests and Criteria, 5th Revised Edition, Amend. 1 and Amend. 2, Section 38.3.2.3.

2. UN 3480, PI 965, Section II. Lithium ion cells and batteries must be offered for transport at a state of charge (SoC) not exceeding 30% of their rated design capacity.

   All packages prepared in accordance with Section II of PI 965 are forbidden for carriage on passenger aircraft. All packages must bear the Cargo Aircraft Only label in addition to the other marks and labels required by the Regulations.

   Not more than one (1) package prepared in accordance with Section II of PI 965 may be placed into an overpack. When the package is placed in an overpack, the lithium battery handling label and Cargo Aircraft Only label required by this packing instruction must either be clearly visible or the label must be affixed on the outside of the overpack and the overpack must be marked with the word “Overpack”.

3. UN 3090, PI 968, Section II. A shipper is not permitted to present for transport more than one (1) package prepared according to Section II in any single consignment.

   Not more than one (1) package prepared in accordance with Section II of PI 968 may be placed into an overpack. When the package is placed in an overpack, the lithium battery handling label and Cargo Aircraft Only label required by this packing instruction must either be clearly visible or the label must be affixed on the outside of the overpack and the overpack must be marked with the word "Overpack".

4. Packages prepared according to Section II of PI 965 and PI 968 must be offered to the operator separately from other cargo and must not be loaded into a unit load device (ULD) before being offered to the operator. The 2016 edition of the IATA lithium battery guidance document has been updated to include specific guidance to shippers on how to determine the SoC of a lithium cell or battery.

Recommendations

Operators are responsible for the acceptance, loading, and actual transport of dangerous goods in accordance with the IATA Dangerous Goods Regulations. However, it is strongly recommended that operators, before engaging in the transport of lithium batteries/cells as cargo on passenger or cargo aircraft, conduct a safety risk assessment, in order to establish whether any risk identified is manageable. Such an assessment should include but not be limited to, the types, quantities of lithium batteries/cells being transported, impact from fires originating from other sources as well as mitigations specific to their operation, such as aircraft cargo compartment fire protection systems (if any).

Cognizance should at all be times be taken of all applicable restrictions under Technical Instructions and IATA Dangerous Goods Regulations.

Chapter 3: Cargo Acceptance and Handling

Acceptance

In addition to a comprehensive "acceptance check," which seeks to verify as far as possible that all applicable requirements for packages (and documentation) have been met for fully regulated dangerous goods, ICAO and IATA require measures to be taken to ensure they are not damaged during transport and these are particularly relevant to lithium batteries. For example, packages must be:

- Secured in an aircraft in a manner that will prevent movement.
- Protected against damage:
    - During flight, for example by the movement of baggage, mail, stores or other cargo.
    - During their preparation for transport, for example during handling after acceptance and prior to loading.

Whilst an acceptance check is only required when fully regulated dangerous goods are first accepted for carriage by air, when packages are transshipped operators should verify that markings and labels are still intact (labels must be replaced by the operator if they have become lost, detached or illegible) and packages are free from damage.

In the event of further regulatory changes, extra provisions may be required to ensure full compliance.

Loading

There are no specific requirements addressing where lithium batteries should be loaded on an aircraft. Operators may wish to consider loading them in a "Class C" cargo compartment,

That is, one in which:

- There is a separate approved smoke detector or fire detector to give a warning to the flight crew.
- There is an approved built-in fire extinguishing system controllable from the flight deck.
- There are means of excluding hazardous quantities of smoke, flames or extinguishing agent from any compartment occupied by the crew or passengers.
- There are means of controlling ventilation and draughts within the compartment so that the extinguishing agent used can control any fire that may start within the compartment.

Furthermore, as an item of dangerous goods in Class 9 (miscellaneous dangerous goods), there is no requirement for packages of lithium batteries to be segregated from other types of dangerous goods. However, operators may wish to consider segregating packages of fully regulated lithium batteries from packages of other dangerous goods except those of classes 6, 7 or 9.

The measures above may be achievable for lithium batteries which are declared to the operator by way of a shipper's declaration. However, section II lithium batteries are not required to be accompanied by a shipper's declaration and consequently operators may wish to consider the pre-notification of such batteries, which may be achieved by an approval process (see below).

Operator Approval

The incidents that have occurred have invariably been caused by non-compliance, but not all have been "undeclared" i.e. they may have been accompanied by a shipper's declaration, but may not have been adequately protected against short-circuit. Consequently, operators may wish to consider, as one of the myriad of available risk mitigation controls, accepting lithium batteries only from shippers and freight forwarders that they have approved. Such approval could seek to satisfy that requirements such as UN testing, protection against short circuit, the correct use of packaging and all training requirements have been satisfied.

General Cargo

Clearly, the above measures are not possible for lithium batteries that have not been declared to the operator. Therefore, efforts must be made to detect such batteries. These could include implementing:

- Enhanced cargo acceptance processes and training to better detect non-compliant shipments. This could include greater scrutiny of the descriptions of goods on accompanying paperwork. For example, items described on an air waybill as "electrical/electronic equipment" or "film crew and media equipment" may contain lithium batteries.
- Additional training for cargo terminal personnel to increase awareness of the need to better detect damaged packages, remove damaged packages from the transport stream, etc.
- In cases where lithium batteries and cells are not accepted on a flight (for either regulatory or airline imposed embargo), it is advisable to carry out risk-based screening and it may be necessary to conduct 100% screening of cargo. In line with the philosophy of Safety Risk Assessment (SRA) particular to an operation, each carrier should review based upon the sphere of operation, customer/client base and likely exposure to risk.

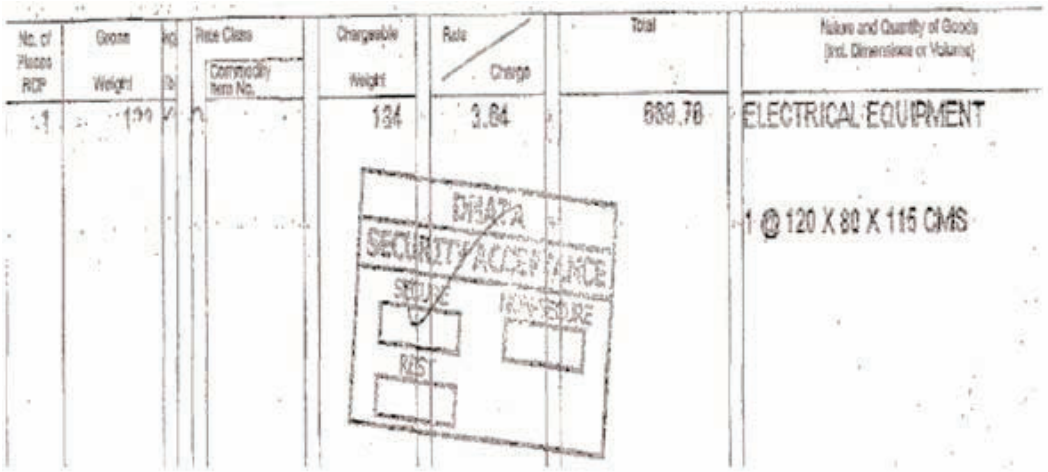


Figure 3.1. The consignment for this air waybill contained lithium batteries

Training

It is recommended that cargo personnel undertake additional, specific, training on the subject of lithium batteries so as to increase awareness of their hazards. Guidance on how to deal with damaged packages, including the possible need to remove them from the transport chain, should also be provided.

Chapter 4: Passenger/Crew Baggage

4.1 Requirements

The widespread usage of portable electronic devices (PED) means that all passenger aircraft will be carrying lithium batteries in baggage. On large aircraft, the number of PED's on board could be in the hundreds. Although they are "dangerous goods," the IATA Dangerous Goods Regulations permits certain types and quantities to be carried by passengers and crew.

General Requirements

General provisions applying to both lithium ion and lithium metal batteries:

- It is recommended that PED's containing lithium batteries be carried in carry-on baggage. However, if this is not possible and they are in checked baggage, measures must be taken to prevent their unintentional activation.
- Batteries and cells must have successfully passed the tests required by the United Nations. Clearly, this would be very difficult, if not impossible, for passengers or check-in staff to determine. However, batteries obtained from reputable sources, such as the original manufacturer, as opposed to market traders, will have been tested appropriately.

Spare batteries (i.e. those not contained in a PED) MUST be:

- In carry-on baggage; they are forbidden in checked baggage (see below regarding actions to be taken at check-in).
- Protected against short circuit, such as by
  - leaving the batteries in original retail packaging,
  - placing them in a plastic bag, such as those supplied at airport security points for liquids and gels, or taping the exposed terminals.

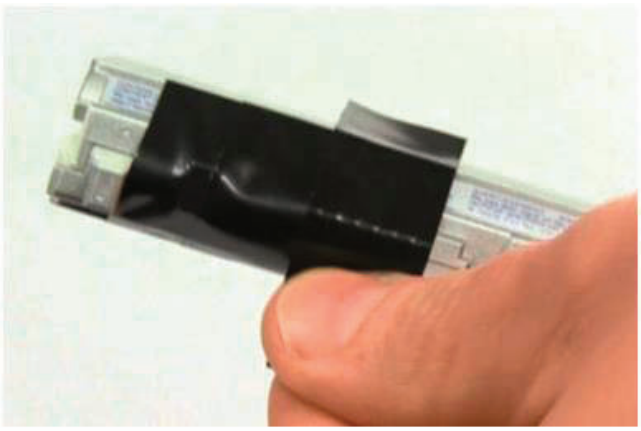


Figure 4.1. Protecting the exposed terminals of a spare laptop battery with insulation tape

There is no limit on the number of PED's or spare batteries, below a specified size, that a passenger or crewmember may carry, but they must be for "personal use." For example, a battery salesperson is not permitted to carry lithium batteries for commercial reasons.

Specific Requirements

Lithium batteries must not exceed the following specifications:

Lithium ion: a Watt-hour rating not exceeding 100 Wh.

This provides for the vast majority of batteries contained in laptop computers, mobile phones and tablets. All new lithium ion batteries will be marked with the Wh rating.

Watt-hour rating exceeding 100 Wh, but not exceeding 160 Wh.

At their discretion, operators may approve the carriage of PED's containing lithium batteries up to 160 Wh (with no more than two spares per passenger), subject to the general provisions above. It is important for operators to clearly state in their manuals, procedures, etc. what is required for such an approval and the person(s) or post holder(s) within the company responsible for granting the approval.

Lithium metal batteries, a lithium content of not more than 2 grams (equivalent to AA size or below)

Lithium metal batteries are non-rechargeable and are typically used in cameras, calculators and watches. Lithium metal batteries are not marked with the lithium metal content, but an AA lithium metal battery contains approximately 0.9 g of lithium.

Battery-Powered Mobility Aids

Non-spillable batteries (i.e. not lithium ion batteries) power the majority of mobility aids for persons with reduced mobility. But, increasingly, passengers are requesting to travel with mobility aids powered by lithium batteries. When fitted to a non-collapsible mobility aid, there is no limit on the Watt-hour rating of lithium batteries. Some mobility aids may have lithium batteries with Watt-hour ratings of as much as 700 Wh. Therefore, operators will need to make a considered judgment as to whether they wish to carry such devices, taking legislation regarding the accessibility of persons with reduced mobility into account.

The requirements for mobility aids powered by lithium batteries are as follows:

- Carriage is subject to approval of the operator.
- Batteries and cells must meet all standards of the United Nations Manual of Tests and Criteria.
- Operators must verify
    - the battery is securely attached to the mobility aid,
    - the battery terminals are protected from short circuits (e.g. by being enclosed within a battery container),

  - electrical circuits have been isolated (note: this does not necessarily mean that the battery has to be disconnected).
- Carriage must be in such a way that the mobility aid cannot be damaged by the movement of other items in the hold.

Some lithium battery-powered mobility aids are collapsible and are specifically designed to allow batteries to be removed by the user. For this type of mobility aid, the following additional requirements apply:

- Batteries must be removed from the mobility aid according to the manufacturer's instructions.
- Batteries must be carried in the passenger cabin.
- The battery terminals must be protected from short circuit by insulating the terminals (e.g. by taping over exposed terminals).
- The battery must be protected from damage (e.g. by placing it in a protective pouch provided by the passenger).
- The battery must not exceed 300 Wh.
- One spare battery not exceeding 300 Wh or two spares not exceeding 160 Wh each may also be carried.
- The pilot-in-command must be informed of the location of the batteries.

Figure 4.2. Collapsible lithium battery powered mobility aid

Portable Medical Electronic Devices

Portable medical electronic devices such as automated external defibrillators (AED), nebulizers, continuous positive airway pressure (CPAP), etc. containing lithium metal or lithium ion cells or batteries are permitted in carry-on baggage or on the person of the passenger, subject to the following conditions:

- They must be carried for medical use.
- Batteries and cells must meet all standards of the United Nations Manual of Tests and Criteria.
- Each installed or spare battery must not exceed the following:
    - for lithium ion batteries, a Watt-hour rating of not more than 160 Wh,
    - for lithium metal batteries, a lithium content of not more than 8 grams.
- No more than two spare batteries per passenger, which must be individually protected against short circuit.

4.2 Passenger Check-In

As stated previously, spare lithium batteries are not permitted in checked baggage. Consequently, if there is a need for hand baggage to be loaded in the hold (e.g. because cabin baggage stowage areas are full), check-in, passenger handling staff or cabin crew should ask affected passengers whether their baggage contains spare lithium batteries and, if it does, the batteries must be removed and carried in the cabin.

Where passengers advise cabin crew that they have spare lithium batteries in their checked baggage, this must be brought to the attention of ground staff if the aircraft is still at the gate so that the bag can be retrieved. If the aircraft has commenced push back or is in flight the cabin crew should report the matter to the flight crew. This must be followed up by submission of an appropriate incident report in accordance with the operator's procedures.

4.3 Small Vehicles Powered by Lithium Batteries

During the latter part of 2015, there was significant media attention on the issue of hover boards, with some very high profile incidents being reported. None of the reported incidents have been while the devices were in air transport, but rather have been primarily while the devices were being charged, with one reported incident while the hover board was in use. Some examples of these small lithium battery-powered vehicles are: airwheel, solowheel, hoverboard, mini-segway, balance wheel.

Discussion took place within the ICAO Dangerous Goods Panel as to how these devices should be treated for the purposes of the provisions of Dangerous Goods Carried by Passengers and Crew, DGR Subsection 2.3. The panel came to the conclusion that these devices are not "mobility aids", but should be treated as "portable electronic devices" (PED) on the basis that the item subject to the Regulations is the lithium ion battery that powers these devices.

As these small lithium battery-powered vehicles do meet the definition of "vehicles" as set out in Special Provision A21, and as they are powered by a lithium ion battery then the correct classification for these small vehicles is UN 3171, **Battery-powered vehicle** and therefore must be packed in accordance with Packing instruction 952.

The allowance for passengers or crew to have PED in their checked or carry-on baggage is determined by the size (Watt-hour rating) of the lithium ion battery as follows:

- where the lithium ion battery does not exceed 100 Wh passengers and crew may have these devices in either checked or carry-on baggage. Approval of the operator is not required;
- where the lithium ion battery exceeds 100 Wh but does not exceed 160 Wh passengers and crew may have these devices in either checked or carry-on baggage, but the approval of the operator is required; and
- where the lithium ion battery exceeds 160 Wh the device is forbidden from being in either passenger or crew checked or carry-on baggage.

In areas and cities where these devices are readily available, operators should ensure that passenger handling staff and the ground service provider, where applicable, are made aware that these devices are subject to the restrictions applicable to PED as set out above.

Operators should consider developing posters, notices or other material with pictures or images of these small lithium battery-powered vehicles for display on their websites, at self-serve kiosks and check-in counters, specifically at airports serving cities where these devices are available, to alert passengers to the conditions applicable to their carriage in checked or carry-on baggage.

At these airports, the operators may wish to bring this matter to the attention of the airport operator's committee so that a coordinated and consistent message is presented to passengers. The airport operator's committee may also wish to coordinate with the airport operator to ensure that on-airport retailers are made aware of the restrictions that apply to the carriage of these devices by passengers, and potentially the restriction on sale to passengers where the operator does not approve the carriage of PED with a lithium ion battery that exceeds 100 Wh.

It is recommended that operators include the following in their operational manuals, or instructions to passenger service staff to address the passenger carriage of these small lithium battery-powered vehicles:

Personnel, including those of ground service providers, must verify that:

- the devices are protected against accidental activation by either being in the original
- manufacturer's packaging or by taping over the on/off switch;

- the Watt-hour rating of the lithium ion battery in the device does not exceed 160 Wh. All lithium ion batteries are required to have the Watt-hour rating marked on the outside of the battery case. If passenger handling staff are unable to verify the Watt- hour rating by checking either the battery, or the user documentation, it is recommended that the passenger be advised that the device cannot be carried;

Note: The watt-hour rating is calculated by multiplying the voltage (V) by the ampere hours (Ah). Where the amperage is shown as milliampere hours (mAh) divide the mAh value by 1,000 to establish the Ah.

If cabin crew identify that the device does not meet the operator's requirement during boarding, they should refer to the ground personnel for proper offloading.

It is recommended that operators restrict these devices to carry-on baggage.

However, PED as carry-on baggage are subject to specific operator restrictions on the size and weight of baggage permitted in the cabin.

4.4 Onboard the Aircraft

There have been a number of incidents where mobile phones have been dropped by passengers into the workings of their seat and crushed when the seat was moved. This scenario is most likely to occur in electrically powered seats found in premium cabins. To reduce the likelihood of this happening it, is suggested that operators incorporate advice into the pre-flight briefing, such as:

> "If you are intending to sleep during the flight please make sure any small electronic devices such as mobile phones, mp3 players and tablets are stowed safely either in seat pocket, a bag or in an overhead locker so that they don't fall into the seat mechanism where they may be damaged. If you do lose your electronic device in your seat, do not move the seat and contact a member of the crew."

Another occasion when lithium batteries could potentially cause an incident is when they are being replaced in onboard equipment such as credit card readers. While this is being done, care must be taken to ensure that neither the old nor the new batteries are dropped into inaccessible locations, where short-circuiting could occur and lead to a fire.

More details on dealing with lithium battery incidents in the cabin can be found in Chapter 5.

Chapter 5: Training and Procedures

Because of the prevalence of lithium batteries and their inherent properties, incidents may occur in baggage, cargo and mail whether through non-compliance with the air transport requirements, or through subsequent damage. Possibly the greatest mitigation factor, is the appropriate training of all staff to be able to intervene in an incident or, better still, prevent an incident from occurring.

Staff are required to be trained "commensurate with their responsibilities" and it is important for operators to consider the extent to which staff need to be trained.

With respect to lithium batteries, training is either:

Preventative (i.e. to stop an incident from occurring) and is generally relevant to staff handling cargo, mail and baggage before flight (e.g. dangerous goods and cargo acceptance staff, loaders, passenger handling staff, etc.). Other staff (e.g. cabin crew) can also have a preventative role. Training should concentrate on detection of:

- Damaged packages.
- Lithium batteries not in compliance with the requirements, for example:
    - where indications on a package suggest a consignment of lithium batteries has not been declared to the operator,
    - where batteries are carried improperly in baggage.

or

Reactive (i.e. to respond to an incident involving fire, smoke or fumes) and is relevant to flight and cabin crew. It is essential that, in addition to general familiarization training, flight and cabin crew receive comprehensive safety training to cover the hazards presented by lithium batteries, including safe handling and emergency procedures.

Safety Training for Flight Crew

As with any cargo fire, the options available to flight crew are severely limited. Without being able to see a burning package, it is impossible for flight crew to know whether lithium batteries are involved, or indeed, whether the smoke/fire warning is genuine. It must be appreciated that the notification to Captain (NOTOC) will only detail fully regulated dangerous goods. It should not be assumed that, if lithium batteries are stated on the NOTOC, they are the source of the fire. Similarly, the absence of lithium batteries on the NOTOC does not necessarily mean that none are being carried; there is always the possibility of undeclared lithium batteries in cargo.

Flight crew should be trained to respond to an emergency suspected of involving lithium batteries carried as cargo by following the standard operating procedure for smoke or fire events, the most important aspect of which is: **LAND AS SOON AS POSSIBLE.**

Cargo Aircraft

Flight crew of cargo aircraft have options not available to those of passenger aircraft. Experience has shown that once a fire has become uncontrollable, a catastrophic situation can develop quickly and it may not be possible to reach a suitable airport in time to land. Should a suitable airport not be within reach, it may be necessary to verify that the smoke/fire warning on the main cargo deck is genuine by visual inspection. Fight crew can also establish the extent and severity of the fire at this time. If this cannot be achieved from the flight deck (e.g. through a porthole), it may be necessary to investigate further. Ideally, someone other than a member of the operating crew should do this, but this may not always be possible (i.e. the operating crew may be the only occupants). If a closer visual inspection is required, this should be done with extreme caution. Flight crew may achieve this by opening the flight deck door as little as possible to obtain a view of the cargo compartment. However, if this is not possible, it may be necessary to access the cargo compartment using appropriate personal protective equipment (PPE) such as fire gloves and portable breathing equipment (PBE). It is important to close the flight deck door after entry into the cargo compartment. The following are the objectives of visual inspection:

- Determine whether smoke or fire is present. If there are no signs of smoke or fire, it must not be assumed that the warning was false, and the appropriate procedures, including landing as soon as possible, should still be followed. The situation should be monitored regularly for the remainder of the flight.
- If smoke is present, and a small fire is the obvious source, it may be possible to extinguish the fire using a portable on-board fire extinguisher. After the fire is extinguished, if it is apparent that lithium batteries were involved, they should be doused with copious amounts of water to cool them and prevent reignition. After this has been done, the crewmember should return to the flight deck and the appropriate procedures for smoke/fire on the main deck should be followed, with the affected cargo being regularly monitored for the remainder of the flight for any signs of smoke or fire.
- If it is apparent that a large fire is present, no attempt should be made to enter the main deck. In this instance, as well as following the appropriate procedures, consideration should be given to the possibility that continued flight may not be possible and other options (e.g. ditching, forced landing) may need to be considered.

Clearly, the presence of fire on board an aircraft is an extremely stressful situation for flight crew, which can be made worse should smoke penetrate the flight deck. Consequently, practical emergency training should address the difficulties that will be encountered in continuing to control an aircraft if there is smoke on the flight deck.

Lithium Battery Fires on the Flight Deck

There are a number of pieces of equipment on the flight deck that are powered by lithium batteries, for example, electronic flight bags and emergency torches (flashlights). In addition, the crew may have a number of personal electronic devices. In the event of one of these items failing and causing a fire, it is understandable that there may be reluctance to introduce liquid into the flight deck. However, if the battery is not cooled with water (or other non-flammable liquid), the fire may continue to propagate. In addition, cabin crew (or indeed, flight crew) may be severely injured when trying to move a burning lithium battery without first dousing the flames and cooling it with water.

There is no "one size fits all" procedure for dealing with a lithium battery fire on the flight deck as some aircraft may be more affected by water ingress than others may. ***Operators are encouraged to consider this when developing their standard operating procedures for dealing with a lithium battery fire on the flight deck, which should be done in conjunction with the aircraft manufacturer.***

Safety Training for Cabin Crew

Cabin crew are most likely to have to deal with an inflight lithium battery fire and as such, have a vital role to play. Because a fire in the cabin can quickly become uncontrollable, with potentially disastrous consequences, it is vital that cabin crew are trained to respond quickly, using the procedures and checklists published in the ICAO Emergency Response Guidance for Aircraft Incidents Involving Dangerous Goods, Doc 9481 (The "Red Book") and IATA's Cabin Operations Safety Best Practices Guide. These procedures have been developed by the IATA Cabin Safety Task Force in conjunction with ICAO and have been incorporated into the 2015 – 2016 edition of the Red Book and details of this material is follows:

Overheat Event

If an electrical smell from a portable electronic device (PED) is detected, or a PED is suspected of overheating, the passenger should be asked to turn off the device immediately. If the PED is plugged into the aircraft power supply the power supply should be disconnected if safe to do so and the in-seat power should also be turned off. Although a PED may be "off," unstable batteries can still ignite and so the PED must remain off and monitored closely for the remainder of the flight.

Fire Event

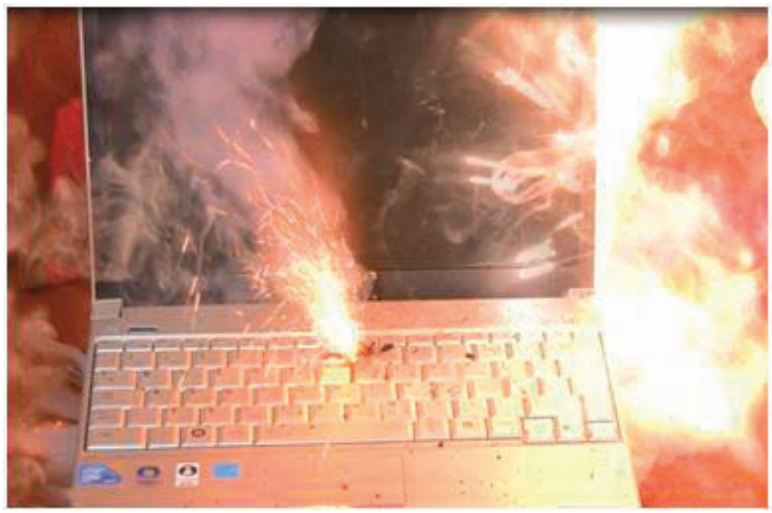


Figure 5.1. A burning laptop

As with any fire occurring in the cabin, the use of personal protective equipment (PPE) such as fire gloves and portable breathing equipment should be considered, but it is important this does not delay the response to the incident. Although following guidance presents a sequence of tasks, some of these actions occur simultaneously when carried out by crewmembers.

1. Identify the item

It may not be possible to identify the item (source of fire) right away, especially if the fire has started in a seat pocket or the device is not readily accessible. In this case, fire-fighting procedures should be applied as a first step. Once it is possible to do so, identify the item after the fire is under control. If the item is contained in baggage, the crew's actions would be similar to the actions for a device that is visible or readily accessible.

Caution: In order to avoid injury from a flash fire, it is not recommended to open the affected baggage when there is any indication of smoke or flames. However, in certain situations cabin crewmembers may assess and deem it necessary to slightly open baggage to allow entry of the extinguishing agent and non-flammable liquid. This should be done with extreme caution and only after donning appropriate protective equipment, available on the aircraft.

2. Apply fire-fighting procedure

Any occurrence concerning a fire in the cabin should be notified immediately to the pilot-in-command who should be kept informed of all actions taken and of the effect. It is essential that the cabin crew and the flight crew coordinate their actions and that each are kept fully informed of the other's actions and intentions.

Appropriate fire-fighting and emergency procedures must be used to deal with any fire. In a multi-cabin crew operation, the actions detailed in the fire-fighting procedure should be conducted simultaneously. On aircraft operated with only one cabin crewmember, the aid of a passenger should be sought in dealing with the situation.

Halon, Halon replacement or water extinguisher should be used to extinguish the fire and prevent its spread to additional flammable materials. It is important to wear available protective equipment (e.g. protective breathing equipment, fire gloves) when fighting a fire.

If fire develops, cabin crew should take prompt action to move passengers away from the area involved and, if necessary, provide wet towels or cloths and give instructions for passengers to breathe through them. Minimizing the spreading of smoke and fumes into the flight deck is critical for the continued safe operation of the aircraft, therefore it is essential to keep the flight deck door closed at all times. Crew communication and coordination is of utmost importance. The use of the interphone is the primary means of communication unless the interphone system fails.

Fire in a Baggage Compartment (e.g. wardrobe or overhead locker)

If fire or smoke is seen coming from a baggage compartment such as a wardrobe or overhead locker, passengers should be moved and asked if they are carrying anything that could be the cause. The exact location of the fire should be determined by checking for heat with the back of an ungloved hand.

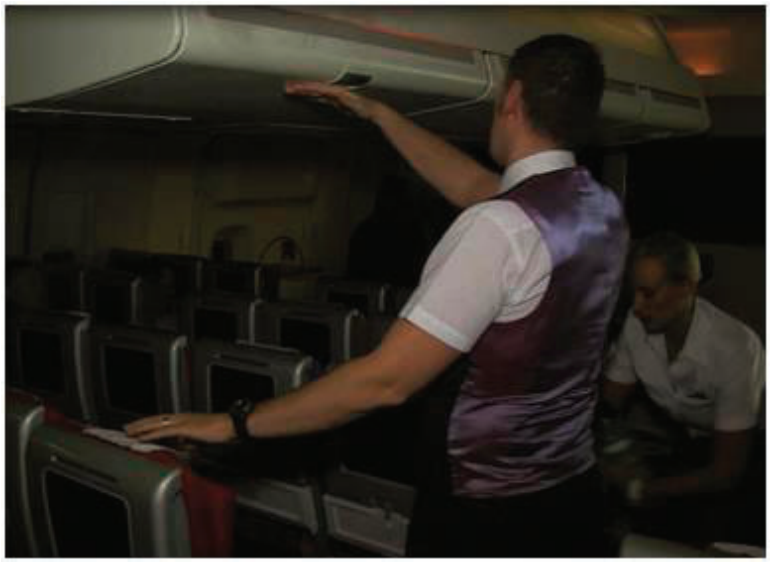


Figure 5.2. Determining the location of a fire in an overhead locker

After first considering the use of PPE, a fire extinguisher should be discharged into the locker.

Figure 5.3. Discharging a fire extinguisher into an overhead locker

The compartment should be closed and a few seconds allowed for the extinguishant to take effect. Further extinguishant should be discharged until it is safe to fully open the compartment, when the cause of the fire must be located.

3. Remove power

It is important to instruct the passenger to disconnect the device from the power supply, if it is deemed safe to do so. A battery has a higher likelihood of catching fire due to overheating during or immediately following

a charging cycle, although the effects may be delayed for some period of time. By removing the external power supply from the device, it will be assured that additional energy is not being fed to the battery to promote a fire.

Turn off the in-seat power to the remaining electrical outlets until it can be assured that a malfunctioning aircraft system does not contribute to additional failures of the passengers' portable electronic devices.

Visually check that power to the remaining electrical outlets remains off until the aircraft's system can be determined to be free of faults, if the device was previously plugged in.

The removal of power may occur simultaneously to other cabin crew actions (e.g. obtaining water to douse the device). Depending on the aircraft type, in-seat power may have to be turned-off by the flight crewmembers.

Caution: Do not attempt to remove the battery from the device.

4. Douse the device with water (or other non-flammable liquid)

If the PED is not in a bag or it is an a bag which is not intact it should not be moved but cooled *in situ* by flooding it with water (or other non-flammable liquid) to prevent the spread of heat to other cells in the battery. If water is not available, any non-flammable liquid may be used to cool the device. If a PED is contained in an *intact* bag and no flames can be seen, the bag should be removed and placed in a watertight container (or one made watertight by using a bin liner) and flooded with water.

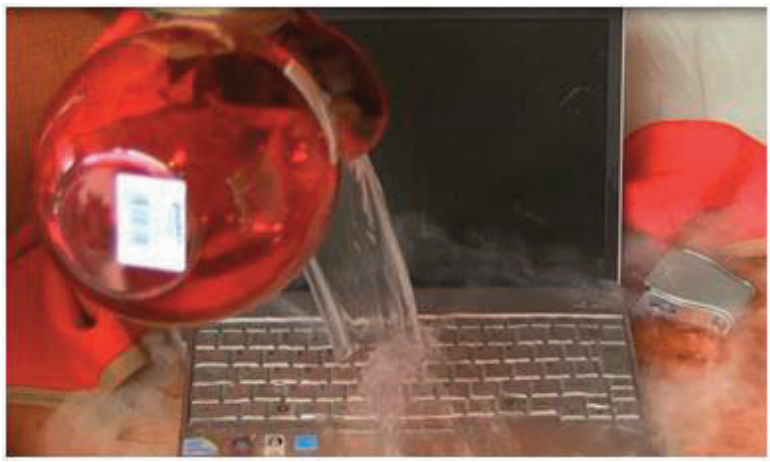


Figure 5.4. A lap top being doused with water from the galley

Figure 5.5. Applying water to a lap top computer without removing it from an overhead locker
Note – Liquid may turn to steam when applied to the hot battery.

Caution:

(i) Do not attempt to pick-up or move the device; batteries may explode or burst into flames without warning. The device must not be moved if displaying any of the following: flames/flaring, smoke, unusual sounds (such as crackling), debris or shards of material separating from the device;

(ii) Do not cover or enclose the device as it could cause it to overheat; and

(iii) Do not use ice or dry ice to cool the device. Ice or other materials insulate the device, increasing the likelihood that additional battery cells will reach thermal runaway.

Figure 5.6. A demonstration of the effect of applying ice to a burning lap top (courtesy of the Federal Aviation Administration)

5. Leave the device in its place and monitor for any re-ignition

A battery involved in a fire can re-ignite and emit flames multiple times, as heat is transferred to other cells in the battery. Therefore, the device must be monitored regularly to identify if there is any indication that a fire risk may still exist. If there is any smoke or indication of fire, the device must be doused with more water (or other non-flammable liquid).

6. When the device has cooled (after approximately 10-15 minutes)

The device can be moved with caution once it has cooled down and if there is no evidence of smoke, heat, or if there is a reduction in the crackling or hissing sound usually associated with a lithium battery fire (after approximately 10-15 minutes). The waiting period may vary, based on the device and its size. The waiting period may vary based on the device and its size. The different circumstances (e.g. types of devices, phase of flight, etc.) should be addressed in the operator's training program.

A suitable empty container, such as a pot, jug, galley unit or toilet waste bin, must be filled with enough water or non-flammable liquid to completely submerge the device. It is important to wear available protective equipment (e.g. protective breathing equipment, fire gloves), when moving any device involved in a fire. Once the device is completely submerged, the container used must be stowed and, if possible, secured to prevent spillage.

Figure 5.7. A lap top computer in a bag being submerged in water in a toilet waste bin....

Figure 5.8. which should be stowed in a bathroom

Not all containers are watertight, so plastic bin liners should be used if necessary.

Figure 5.9. A bar box made water-tight using a plastic bin liner

Lithium Battery Fire Prevention – Portable electronic device inadvertently crushed or damaged in electrically adjustable seats

There have been reported incidents by airlines related to incidents on board as a result of the inadvertent crushing or damage of a portable electronic device (PED). As a result some have caught fire.

Figure 5.10. A mobile phone crushed in an electrically adjustable seat

Figure 5.11. The charred remnants

Small portable electronic devices (PED's) such as mobile phones, smartphones, mini-tablets, e-readers or MP3 players etc. can become a potential fire hazard if they inadvertently slip or are dropped between the mechanical parts of an electrically adjustable seat and are crushed or damaged. These types of seats are primarily installed in premium class cabins such as First Class and Business Class.

Due to the design of some electrically adjustable passenger seats, it is possible that a PED can slip under a seat covering and/or cushion, behind an armrest or down the side of a seat. Cabin crew should not move the

seat electrically or mechanically when attempting to retrieve the passenger's PED. The seat movement may crush/damage the PED's lithium battery and potentially result in a lithium battery fire.

Passenger awareness on how to use and stow their devices while in flight can help mitigate these incidents. (See Chapter 3).

Recommended Practice

To prevent crushing of the PED and reduce the potential fire risk to the device and the surrounding area, cabin crew, and/or passengers ***must not use the electrical or mechanical seat functions in an attempt to retrieve a PED***. Cabin crew should always advise the flight deck of the situation. Ask the passenger concerned to identify the item, and where they suspect it may have dropped or slipped into, and if they have moved the seat since misplacing the PED. Move the passenger and, if applicable, the passenger seated next to the affected seat from the area. If available, don fire gloves before trying to retrieve the item. ***Do not move the seat!*** If unable to retrieve the item, it may be necessary to move the passenger to another seat.

Due to the design of some electrically adjustable passenger seats, it is possible for a PED to slip under a seat covering and/or cushion, behind an armrest or down the side of a seat. Passengers and cabin crew should not move the seat electrically or mechanically in order to attempt to retrieve the passenger's PED. The seat movement may crush/damage the PED's lithium battery and potentially result in a lithium battery fire.

In the event that the situation develops into a lithium battery fire, cabin crew should apply the following as per their respective airline procedures:

- Lithium battery fire-fighting procedures.
- Post-event procedures (on board).
- First point of landing offloading procedures.

After landing, the crew must advise ground staff where the device is stowed and make an appropriate entry in the technical log. The PED must be removed from the aircraft, as lithium batteries that are damaged are forbidden for carriage. Devices involved in a fire should be retained on the ground to enable investigation by competent authorities.

Considerations for Operators of Small Aircraft

The guidance provided above is based on a large transport aircraft with access to a number of cabin crew. However, smaller aircraft may have only have one or two cabin crew and so some of the actions may need to be combined and/or the assistance of passengers may be needed. Additionally, consideration will need to be given as to what items are available to use in the event of an incident. It is suggested that all aircraft, as a minimum, should carry the following equipment additional to that usually on-board:

- **Fire/heat resistant gloves.**
- **Heavy duty plastic bin liners;** if the aircraft has no suitable container that something the size of a lap top computer can fit in, these can be filled with water before placing the device in it.

- **Suitable receptacles** e.g. jugs, to transfer water from the galley or bathroom should insufficient bottled water be carried.

Testing to Verify Understanding

All staff required to take dangerous goods training are also required to be tested in order to verify their understanding. In the case of cabin crew, it is suggested that this should include a practical demonstration of their competence to deal with a lithium battery incident in the cabin.

Further Guidance

Further guidance on the use of portable electronic devices in the cabin may be found here:
http://www.iata.org/publications/Documents/guidance-use-expansion-peds.pdf

Chapter 6: Current Mitigations and Future Developments

The incidents and accidents that have occurred where lithium batteries are known to have been a factor (or were present on board) have highlighted the vulnerability of cargo aircraft to main deck cargo compartment fires and, in particular, how quickly a situation can become catastrophic. In the first chapter of this manual, we have highlighted some of the accidents and it is clear that the time between first signs of fire and catastrophic loss are relatively short. Consequently, a number of technologies are being investigated by industry and regulators to enhance fire protection, particularly on cargo aircraft as these may not have the same level of fire suppression as passenger aircraft. However, it would be wrong to believe that such measures are necessary only when it is known that lithium batteries are being carried. Undeclared shipments are commonplace; therefore, such provisions should be applied even when no consignments of lithium batteries have been declared to an operator.

At a recent lithium battery workshop, several new and developing technologies were showcased. Some examples of these are shown in the following section.

Fire-Resistant Containers

Containers constructed of fire resistant material, similar to that used in body armor, have demonstrated their ability to contain an internal fire of up to 650°C (1200°F) for at least four hours. They also have the advantage of being lighter than conventional, aluminium, containers, with some offering a weight savings of as much as 30kg (65lb).

Figure 6.1. Fire-resistant containers

In-Container Fire Suppression

Tests are currently being carried out on fire resistant containers, fitted with their own self-contained fire suppression systems that automatically activate when fire or smoke is detected.

Figure 6.2. In-container fire suppression system

Unit Load Device Penetration

This system utilizes penetrators located above each ULD position to automatically pierce the roof of a container from where excessive heat is detected, and deploy fire extinguishant directly into it.

Figure 6.3. ULD fire suppression system, showing penetrators at each ULD position

Fire Containment Covers

Not all cargo is carried in closed unit load devices, much is carried on open pallets. Some operators have implemented use of fire containment covers (FCCs) on pallets whilst others are considering their use. Some FCCs currently in production can contain a fire of up to 815°C for four hours. Like the fire resistant containers, these covers provide protection from an adjacent fire as well as from one within.

Figure 6.4. An open pallet with a fire containment cover

Smoke Displacement Systems

A smoke-filled cockpit can restrict or completely block a pilot's view of the outside and essential cockpit instruments. Vision can be restored by smoke displacement systems, which use self-inflating transparent plastic envelopes to provide a clear space of air through which a pilot can see flight instruments and the outside world.

Figure 6.5. A smoke displacement system (EVAS – Enhanced Vision Assurance System)

In February of 2015, the VisionSafe Corporation received Supplemental Type Certification (STC) for the Emergency Vision System (EVAS) Cockpit Smoke Displacement equipment applicable to the Boeing 777. The Boeing 777 is the latest aircraft to get FAA certified equipment and includes models 777-200, -200LR, -300, -300LR and the 777F. The company now has EVAS STC's for over 80 aircraft types.

The FAA recommends that aircraft meet higher standards for continuous cockpit smoke protection (FAA AC25.109). The Air Line Pilots Association's (ALPA) in-flight fire project reported more than 1,100 in-flight smoke and fire incidents over only 10 months, causing 360 emergency landings.

FAA's concern about smoke continues, this is still a "serious" problem and the statistics are essentially unchanged. Flight Safety Foundation ranks smoke/fire emergencies as the 3rd highest cause of fatalities. Smoke is also a leading cause of diversions of ETOPS aircraft.

Quick-Donning Full-Face Oxygen Masks

Unlike traditional flight crew oxygen masks, which require two hand to don, new face masks can be donned with only one hand and in only a couple of seconds. These new masks can be used in conjunction with smoke displacement systems.

Figure 6.6. Quick-donning full-face oxygen mask

Enhanced Packaging Standards

Enhanced packaging standards for lithium batteries are being evaluated by regulators and packaging manufacturers. However, while this will make compliant consignments even safer, it will have no effect on the biggest danger (i.e. non-compliant, undeclared batteries).

Enhanced Security Screening

The algorithms of X-ray machines used in security screening are currently set to detect explosives automatically. Research being conducted by the United Kingdom Civil Aviation Authority is exploring the feasibility of detecting lithium batteries in cargo using existing x-ray technology.

Chapter 7: Further Information

Passenger baggage

IATA

"What's your type – Information for Airline Passengers on Lithium Batteries":
http://www.iata.org/whatwedo/cargo/dgr/Documents/passenger-lithium-battery.pdf

United States Federal Aviation Administration (FAA)

"Travelling safely with batteries and battery powered devices":
http://safetravel.dot.gov/whats_new_batteries.html

UK Civil Aviation Authority (CAA)

"One team, one goal" guidance on the carriage of battery powered mobility aids (video)
http://www.youtube.com/watch?v=IFyEVckQEjc

Civil Aviation Safety Authority (CASA)

Portable Electronic Devices containing Lithium Metal or Lithium Ion Cells or Batteries
http://www.casa.gov.au/scripts/nc.dll?WCMS:STANDARD::pc=PC_100484

Passengers warned of lithium battery safety risk
http://www.casa.gov.au/scripts/nc.dll?WCMS:STANDARD::pc=PC_100547

Dangerous goods that may be carried by passengers and crew
https://www.casa.gov.au/sites/g/files/net351/f/_assets/main/manuals/regulate/aocm/220rfull_vol4.pdf

Dangerous Goods Lithium poster
http://www.casa.gov.au/wcmswr/_assets/main/dg/luggage/lithium_battery_poster.pdf

Cathay Pacific:

General advice to passengers: http://www.cathaypacific.com/cpa/en_INTL/helpingyoutravel/batteries#I

Cargo

IATA

Main site for lithium battery advice: http://www.iata.org/whatwedo/cargo/dgr/Pages/lithium-batteries.aspx

Lithium Battery Shipping Guidelines: http://www.iata.org/publications/Pages/lithium-battery-guidelines.aspx

Mail

UK Royal Mail

Guidance to business customers:
http://www.royalmail.com/sites/default/files/DangerousGoods_BusinessCustomerBooklet_July2013_0.pdf

Guidance to the public: http://www.royalmail.com/sites/default/files/International-prohibitions-and-restrictions-leaflet-consumers_0.pdf

Emergency response

IATA

Guidance on Handling Dangerous Goods Incidents and Lithium Battery Fires in the Passenger Cabin
http://www.iata.org/whatwedo/safety/Documents/Guidance-on-Handling-Dangerous-Goods-Incidents-and-Lithium-Battery-Fires-in-the-Passenger-Cabin.pdf

United States Federal Aviation Administration (FAA)

Extinguishing In-flight Laptop Computer Fires (video)
http://www.fire.tc.faa.gov/2007Conference/session_details.asp?sessionID=26

UK Civil Aviation Authority (CAA)

CAA Paper 2003/4 – "Dealing with In-Flight Lithium Battery Fires in Portable Electronic Devices"
http://www.caa.co.uk/docs/33/capap2003_04.pdf

Transport Canada

Service Difficulty Alert – "Procedures for Fighting Fires Caused by Lithium Type Batteries in Portable Electronic Devices" http://www.tc.gc.ca/eng/civilaviation/certification/continuing-alert-2009-06-698.htm

Testing

FAA

DOT/FAA/AR-06/38 – Flammability Assessment of Bulk-Packed, Rechargeable Lithium-Ion Cells in Transport Category Aircraft: www.fire.tc.faa.gov/pdf/06-38.pdf

DOT/FAA/AR-04/26 – Flammability Assessment of Bulk-Packed, Non-rechargeable Lithium Primary Batteries in Transport Category Aircraft: www.fire.tc.faa.gov/pdf/04-26.pdf

DOT/FAA/AR-09/55 – Flammability Assessment of Lithium-Ion and Lithium-Ion Polymer Battery Cells Designed for Aircraft Power Usage: http://www.fire.tc.faa.gov/pdf/09-55.pdf

Advice to operators

Boeing

"Lithium battery cargo awareness" http://www.fire.tc.faa.gov/pdf/systems/Nov12Meeting/Boeing-1112-LithiumBatteryCargoAwareness.pdf

"Fire Protection: Cargo Compartments:
http://www.boeing.com/commercial/aeromagazine/articles/2011_q2/3/

FAA

Safety Alert for Operators 10017:
http://www.faa.gov/other_visit/aviation_industry/airline_operators/airline_safety/safo/all_safos/media/2010/SAFO10017.pdf

UK CAA

Flight Operations Department Communication (FODCOM) 30/2010 – The Carriage of Lithium Batteries as Cargo: http://www.caa.co.uk/docs/33/FOD201030.pdf

IATA

http://www.iata.org/whatwedo/safety/Documents/IATA-Safety-risk-assessment-carriage-of-lithium-batteries%20V.2.pdf

Incidents

FAA

"BATTERIES & BATTERY-POWERED DEVICES Aviation Incidents Involving Smoke, Fire, Extreme Heat or Explosion":
http://www.faa.gov/about/office_org/headquarters_offices/ash/ash_programs/hazmat/aircarrier_info/media/Battery_incident_chart.pdf

Accident Reports

General Civil Aviation Authority of the United Arab Emirates

Boeing 747-44AF, N571UP, Dubai, 3 September 2010:
http://www.gcaa.gov.ae/en/ePublication/admin/iradmin/Lists/Incidents%20Investigation%20Reports/Attachments/40/2010-2010%20-%20Final%20Report%20-%20Boeing%20747-44AF%20-%20N571UP%20-%20Report%2013%202010.pdf

Korean Aircraft and Railway Accident Investigation Board

B747-400F, HL7604, 130 km West of Jeju International Airport, 28 July 2011:
http://araib.mltm.go.kr/LCMS/DWN.jsp?fold=/eaib0401/&fileName=Interim+Report%28Asiana+Airlines+Cargo+Flight+991+Accident%29.pdf

National Transportation Safety Board (United States)

McDonnell Douglas DC-8-71F, N748UP, Philadelphia, Pennsylvania, 7 February 2006:
http://www.ntsb.gov/doclib/reports/2007/AAR0707.pdf

New initiatives

UPS

Details of fire resistant containers:
http://www.pressroom.ups.com/Press+Releases/Current+Press+Releases/UPS+Pioneers+Aviation+Safety%2C+Implements+New+Fire-Resistant+Shipping+Containers

Flight Safety Foundation

Article on cargo fire suppression systems: http://flightsafety.org/asw/nov09/asw_nov09_p39-43.pdf?dl=1

Miscellaneous guidance

Flight Safety Foundation

Flight Safety Foundation article on cargo safety:
http://www.flightsafety.org/asw/nov06/asw_nov06_p28-33.pdf?dl=1

www.iata.org/publishing
custserv@iata.org
+1 800 716 6326