



DGP-WG/11-IP/2
21/3/11

**DANGEROUS GOODS PANEL (DGP)
MEETING OF THE WORKING GROUP OF THE WHOLE**

Atlantic City, United States, 4 to 8 April 2011

- Agenda Item 5: Resolution, where possible, of the non-recurrent work items identified by the Air Navigation Commission or the panel:**
5.1: Review of provisions for the transport of lithium batteries

LITHIUM BATTERIES: OUTREACH

(Presented by Adrian Tušek)

The attached article is provided for the information of panel members. The article is a part of the lithium battery outreach program being undertaken in Australia. It is published in the Flight Safety Australia Magazine, Mar-Apr 2011 Issue 79, by the Civil Aviation Safety Authority, Australia.

The cargo from hell

THEY
ARE THE
POWER BEHIND
MODERN CONSUMER
ELECTRONICS, FROM LAPTOP
COMPUTERS TO DIGITAL CAMERAS.
BUT AS UNPREDICTABLE, INTENSE AND
PERSISTENT FIRE STARTERS

+ LITHIUM BATTERIES -

ARE EMERGING AS A 21ST-CENTURY
AVIATION HAZARD.



In the beginning, the flight was about as routine and humdrum as commercial aviation can be. The two pilots were the only occupants of a Boeing 747-400F freighter on a six-hour and 20-minute night flight from Dubai to Cologne/Bonn in Germany. There were no goodbyes at the boarding gate, no entranced passengers gazing out of their windows, just two professionals on the last leg of a regular run that had begun in Hong Kong. Unheralded, they had departed in darkness into the 35-degree heat of the desert night.

But when UPS Airlines flight 006 was about 28 minutes into its journey the fire alarm sounded: smoke on the main cargo deck. It was the first of three warnings of a cargo fire on the doomed flight, investigators from the United Arab Emirates say.

At the time of writing, the multinational investigation team (from the US and the UAE) has not officially determined the cause of the crash on 3 September last year, but has issued details of what confronted the American pilots as they tried to return to Dubai.

The smoke was so dense, investigators said, that the pilots had difficulty in seeing the primary flight instruments, and even in communicating with each other.

They also could not change radio frequencies; so nearby aircraft passed on messages from Dubai controllers.

The crews of these aircraft heard the tragedy unfolding. 'To hear the initial panic and plain fear during their transmissions (in real time as opposed to a DVR playback on a documentary) has been the most chilling event in my 25 years of flying,' a British airline pilot who heard the transmissions wrote in an online forum.

At some point during the emergency, one of the pilots apparently left the flight deck to try to fight the flames but never returned, sources close to the investigation told Andy Pasztor of *The Wall Street Journal*.

Dubai Airport gave the freighter clearance to land on any runway. The aircraft did not descend enough to land, but flew over the airport at 4,000ft, turned right and crashed. Its captain, Doug Lampe, 48, and first officer Matthew Bell, 38, were killed, or were perhaps already dead as a result of the smoke and heat. By sheer luck the plane came down in an unpopulated area and no-one on the ground was hurt.

Just over a month after the crash, and long before the official report had been written, the US Federal Aviation Administration (FAA) issued an unusual and disturbing communiqué. Safety Alert for Operators 10017 concerned the risks of transporting lithium batteries as aircraft cargo, and specifically mentioned UPS 006.

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'Investigation of the crash is still underway, and the cause of the crash has not been determined. We are aware, however, that the plane's cargo did include large quantities of lithium batteries and believe it prudent to advise operators of that fact,' the FAA said.

The inference was clear: lithium batteries were implicated in the destruction of UPS 006.

The implications for international commerce are immense because these batteries make up a large and rapidly growing proportion of international air freight.

Civil Aviation Safety Authority crashworthiness specialist Mark Bathie says tens of millions of lithium batteries are flown every year as luggage or freight.

'One figure I saw, was that in 2009, just one carrier shipped 49 million lithium batteries from seven suppliers.'

US Census Bureau figures show that 66 per cent of mobile phones, 70 per cent of video equipment and 86 per cent of laptops sold in the US were shipped by air in 2009.

The chemistry of lithium batteries makes them both the ideal candidate and a significant risk for air shipment. They are small, valuable and, with a limited shelf life, fit the classic profile of an airfreight item.

'Because they must be shipped in a partially charged state and slowly lose charge over time, manufacturers do not want to waste months putting lithium batteries into warehouses or ships' holds,' Bathie says.

In the absence of an official report there are unanswered questions about whether the lithium batteries carried on UPS 006 were real or counterfeit; had been properly packed; or had been declared, labelled, consigned, accepted and stowed as dangerous goods.

Dangerous goods experts agree that the accident reinforces the need for correct packaging and handling of the new-generation batteries.

While rare in comparison with the number and frequency of flights worldwide, battery-related safety incidents are by no means uncommon on commercial aircraft.

There is some evidence that the problem is growing in step with the increasing popularity of electronic goods. The *6th Triennial International Aircraft Fire and Cabin Safety Research Conference* held in New Jersey last October heard that 34 battery-related incidents have been reported to the FAA since February 2007.

An FAA report found that from 1991 to 2010 there were 113 incidents of 'smoke, fire, extreme heat or explosion' involving batteries and battery-powered devices on passenger and cargo planes. This covered many types of batteries, including lead-acid batteries which, as any mechanic knows, can give off hydrogen and oxygen if overcharged.

In one incident in 2006, flight attendants saw smoke coming from a bag in an overhead locker and had to use fire extinguishers on it, NTSB investigator Frank Hilldrup told a public hearing. 'The bag was removed from the plane and placed on the ramp, where it burst into flames. The fire seemed to have started from a spare laptop battery being carried in the bag.'

Flammability concerns regarding laptop lithium-ion batteries increased between 2006 and 2009 as Dell, Sony, Toshiba and Hewlett Packard were forced to issue recalls for laptop computers that could overheat or burst into flames.

The
elemental
power of lithium
also makes it
DANGEROUS.

As an alkali metal, lithium is a highly reactive element that can store considerable energy in its atomic bonds. This is what gives lithium batteries their very high specific energy. A typical lithium-ion battery can store 150 watt-hours of electricity in a 1kg battery. This compares to about 100 watt-hours for a nickel-metal hydride and 25 watt-hours for a 1kg lead acid battery.

The downside of a lithium-ion battery's high energy is the potential for fire when things go wrong. The abundant energy that makes it an efficient battery also makes it an efficient fire starter.

There are three sub-types of lithium batteries, all of which have the potential to start fires. Lithium metal batteries range from button-sized to AA-sized and are disposable (or primary) batteries.

Lithium-ion and lithium polymer batteries (that use a solid polymer for their electrolyte) are rechargeable (or secondary) batteries found in laptop computers, mobile phones, iPods and other music players, electric bicycles and some power tools. Lithium-ion battery packs are typically made up of a series of cylindrical cells, while lithium polymer batteries can be almost any shape.

Lithium-ion and lithium polymer batteries can explode or catch fire if overcharged. One method of ignition involves tiny lithium particles that form fibres called dendrites. Over several charge/discharge cycles, dendrites grow on the battery's carbon anodes. This can lead to internal short circuits, resulting in overheating and combustion.

Explosions can also occur if the battery is externally short-circuited or its cells are punctured.



CASA dangerous goods inspector, Ben Firkins, says: 'Lithium batteries can be found either in cargo or being carried on by passengers. Whilst the international aviation DG community has been working on the risks presented in carrying batteries, the last few years can be viewed as resulting in some significant progress in cabin safety.'

The FAA's Technical Centre in Atlantic City, New Jersey, is undertaking tests on thermal runaway, auto-ignition and sympathetic initiation of lithium batteries, as well as fire containment and suppression.

It has produced videos which show how cabin crews should approach and treat laptop and lithium battery fires. These have been widely circulated via CASA's cabin safety inspectors and the Australian Dangerous Goods Air Transport Council to Australian operators for use in cabin crew training materials.

Firkins says:

'The preference is for passengers' lithium battery-powered equipment to be carried in the cabin, although provision is still made for it to be carried as checked-in baggage.'

Any spare batteries, however, must have the terminals protected from short circuit and be carried in the cabin. Fires are likely to be small, and confined to one battery, and most will be easily extinguishable by cabin crew. The rationale is similar to allowing cigarette lighters to be carried by passengers (but not in their carry-on baggage). If there is a fire, the passenger will soon know about it and trained cabin crew can deal with it quickly and effectively.'

Dangerous goods experts agree that lithium batteries carried in cargo are the continuing field of focus for compliance.

The FAA's Safety Alert for Operators 10017 reports that lithium batteries can enter a condition called thermal runaway and reach temperatures of nearly 600 degrees Celsius.

Lithium metal batteries produce more severe thermal runaway than rechargeable lithium-ion cells, the FAA trials found 'The lithium metal cell releases a flammable electrolyte mixed with molten lithium metal, accompanied by a large pressure pulse. The combination of flammable electrolyte and the molten lithium metal can result in an explosive mixture.

The study found that lithium ion and lithium-ion polymer batteries, while not quite as dangerous as lithium metal batteries, were more hazardous than previously thought. 'The results of the tests showed that the lithium-ion and lithium-ion polymer battery cells can react violently when exposed to an external fire, Safety Alert 10017 said. 'Under test conditions, when the battery cells failed, flammable electrolyte was released and ignited, which further fuelled the existing fire. This release and ignition of the electrolyte resulted in significant temperature and pressure increases within the test fixtures.'

The FAA made four recommendations in its alert. Airlines should:

- ▶ 1) Request customers to identify bulk shipments of currently excepted lithium batteries by information on airway bills and other documents provided by shippers offering shipment of lithium batteries.
- ▶ 2) Where feasible and appropriate, stow bulk shipments of lithium batteries in Class C cargo compartments, or in other locations where fire suppression is available.
- ▶ 3) Evaluate training, stowage and communication protocols with respect to the transportation of lithium batteries in the event of an unrelated fire.
- ▶ 4) Pay special attention to ensuring careful handling and compliance with existing regulations covering the air transportation of Class 9 hazardous materials, including lithium batteries.

The FAA Technical Centre is continuing its research into lithium battery fires, with projects including an investigation of how well water mist systems work in battery fires; an evaluation of how well shipping containers withstand a lithium battery fire; and development of a standard for lithium battery shipping containers.

Firkins says lithium batteries will, in time, be superseded by other technologies, each with its own risks and benefits: 'New technologies emerge, and in the case of batteries, the newest developing technology is in 'fuel cells'. The International DG community has been active in working with fuel cell manufacturers and the Fuel Cell Council to ensure that these can be transported safely. It is likely that in the future this will have a great impact on the number of lithium batteries being transported. Until then, we have to manage the current risks presented by lithium batteries.

CASA's Melbourne-based dangerous goods inspector and representative on the ICAO Dangerous Goods Panel, Adrian Tusek, says lithium batteries are a global issue and there is an identified need for increased education and compliance.

'In 2009, the rules regarding packing, marking, labelling and declaring lithium batteries, either in equipment or purely as batteries, were significantly strengthened. There was an impost upon consignors and freight forwarders, especially as the new classification and packing criteria meant that these items could no longer travel as air mail.

'We worked with the aviation industry and IATA (International Air Transport Association) to provide some guidance around the new packing instructions for lithium batteries.

'We are yet to see a DG incident or accident involving properly packed and labelled lithium batteries, so our focus will be on educating and encouraging compliance with international standards, with an outreach program in 2011.' ✎

Further READING

Two sites about the classification and packing of lithium batteries:

http://www.iata.org/whatwedo/cargo/dangerous_goods/Pages/lithium_batteries.aspx

<http://www.icao.int/anb/fls/dangerousgoods/icaolithiumbatteryguidance/icaolithiumbatteryguidance.pdf>

The FAA Technical Centre website:

www.fire.tc.faa.gov

The General Civil Aviation Authority of the United Arab Emirates:

www.gcaa.ae/en

Several less-than-scientific but dramatic versions of how lithium batteries burn and explode when overheated, overcharged or damaged by impact:

www.youtube.com/Lithium_battery_explosion