DGP/30-IP/12
10/10/25

DANGEROUS GOODS PANEL (DGP)

THIRTIETH MEETING

Montréal, Canada, 6 to 10 October 2025

Agenda Item 4: Managing safety risks posed by the carriage of energy storage devices by air *(Ref: Job Card DGP.003.05)*

UPDATE ON EASA RESEARCH

(Presented by L. Calleja-Barcena)

SUMMARY

This information paper contains a presentation provided to DGP/30 on a research project on portable electronic device (PED) fire and smoke hazards in the aircraft cabin sponsored by the European Aviation Safety Agency (EASA).

EASA
European Union Aviation Safety Agency

LOKI-PED

Lia Calleja-Barcena
Dangerous Goods Expert
Cabin Crew/Cabin Safety Expert

ICAO Dangerous Goods Panel DGP-30
06-10 October 2025

Your safety is our mission.

An Agency of the European Union

1

EASA research

Research Project details

Contracting Authority: EASA

Project Leader: Fraunhofer Gesellschaft

€ 800,000

08/2022 › 07/2025

This project will be funded from the European Union's Horizon Europe research and innovation programme.

At Frauenhofer Gesellschaft
Project manager: Simon Holz, simon.holz@emi.fraunhofer.de
Technical lead: Victor Norrefeld, victor.norrefeldt@ibp.fraunhofer.de

Consortium members
Airbus

At EASA
Project manager: Simone Schwerdorf, simone.schwerdorf@easa.europa.eu
Technical lead: Lia Calleja Barcena, lia.calleja-barcena@easa.europa.eu
Technical expert: Enzo Canari, enzo.canari@easa.europa.eu

LOKI-PED Project

LOKI-PED

EASA https://www.easa.europa.eu/en/research-projects/loki-ped-lithium-batteries-firesmoke-risks-cabin 3

3

LOKI-PED: Lithium Batteries Fire/Smoke Risks in Cabin

Overview

Sponsor: European Union Aviation Safety Agency EASA

Partners

- Fraunhofer Institute for Highspeed Dynamics, Ernst-Mach-Institute, EMI
- Fraunhofer Institute for Building Physics
- Airbus Operations GmbH & Airbus SAS

including 20 experts, researcher and technicians.

Focus

- Cabin and cockpit
- Not cargo nor checked luggage

Tasks

- Characterization of the main hazards posed by PEDs
- Consequences of fire and smoke in cockpit and cabin
- Risk assessment regarding number and energy content of PEDs
- Assessment of emergency procedures
- Assessment of additional mitigation measures
- Identification of gaps in the regulatory provisions

LOKI-PED

EASA

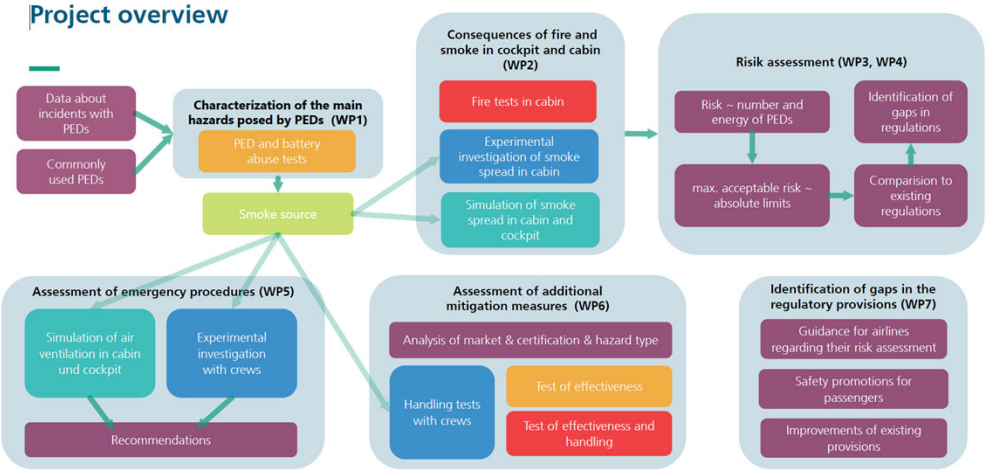
4

4

LOKI-PED

(https://loki-ped.de)

Project overview



EASA

5

5

Battery Test Center – Fraunhofer EMI

Experimental Approach – PED and battery abuse characterization

- → **Battery Test Center**
- → 08/2023 & 06/2024

WP 1

TR and source characterization

Realization: Laptops, Tablets, Smartphones, Power tool batteries are triggered by heating foils

EASA

6

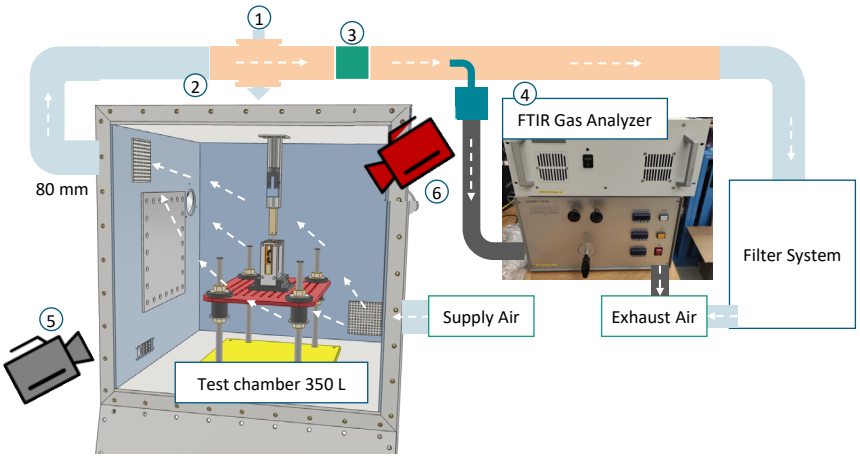
6

Experimental Approach – PED and battery abuse characterization

Battery Test Center – Fraunhofer EMI

PED abuse

Battery Test Center



Diagnostics:

1. Light source / photo detector
   - → *Smoke release rate*
2. Type K thermocouple
   - → *Temperature / heat rate*
3. Flowmeter / Hot-Wire Anemometer
   - → *Volume flow*
4. Gasmet FTIR Gas Analyzer
   - → *Gas composition*
5. Optical video recording
6. InfraTec VarioCAM
   - → *Thermographic images*

EASA

7

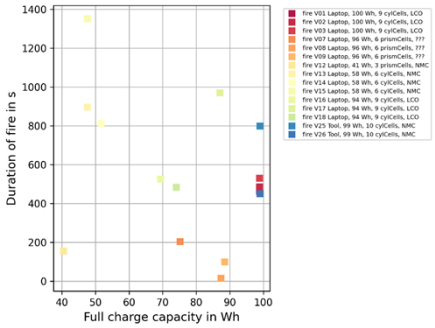
7

PED characterization tests - Summary

Component

Battery Test Center

#	Device	Capacity [Wh]	Cells	Cell Type	Chemistry	Hazard
1	Laptop	100	9	Cylindrical	LCO	Fire
2	Laptop	100	9	Cylindrical	LCO	Fire
3	Laptop	100	9	Cylindrical	LCO	Fire
4	Laptop	100	6	Pouch	LFP	Smoke
5	Laptop	99	6	Pouch	LFP	Smoke
6	Laptop	99	6	Pouch	LFP	Smoke
7	Laptop	96	6	Prismatic	-	Fire
8	Laptop	96	6	Prismatic	-	Smoke
9	Laptop	96	6	Prismatic	-	Smoke
10	Laptop	43	3	Prismatic	NMC	Smoke
11	Laptop	40	3	Prismatic	NMC	Smoke
12	Laptop	40	3	Prismatic	NMC	Smoke
13	Laptop	58	6	Cylindrical	NMC	Fire
14	Laptop	58	6	Cylindrical	NMC	Fire
15	Laptop	58	6	Cylindrical	NMC	Smoke
16	Laptop	94	9	Cylindrical	LCO	Fire
17	Laptop	94	9	Cylindrical	LCO	Fire
18	Laptop	94	9	Cylindrical	LCO	Fire
19	Smartphone	13	1	Pouch	-	Smoke
20	Smartphone	13	1	Pouch	-	Smoke
21	Smartphone	13	1	Pouch	-	Smoke
22	Tablet	43	3	Pouch	-	Smoke
23	Tablet	43	3	Pouch	-	Smoke
24	Tablet	43	3	Pouch	-	Smoke
25	Power Tool	99	10	Cylindrical	NMC	Fire
26	Power Tool	99	10	Cylindrical	NMC	Fire



EASA

8

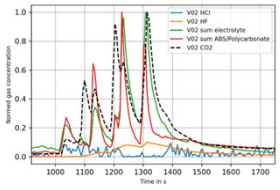
8

Exemplary test results

Battery Test Center – Fraunhofer EMI

PED abuse

Battery Test Center



Smoke hazard

Lithium-Ion battery emissions under thermal runaway

Polymer fire resulting from casing of both PED and battery

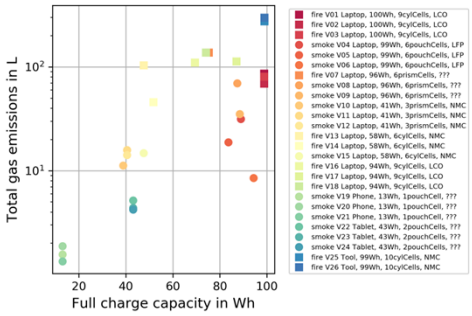
Flammable and toxic gases

Fresh air ventilation

Fire hazard

Post test inspection

Battery emissions under thermal runaway



EASA

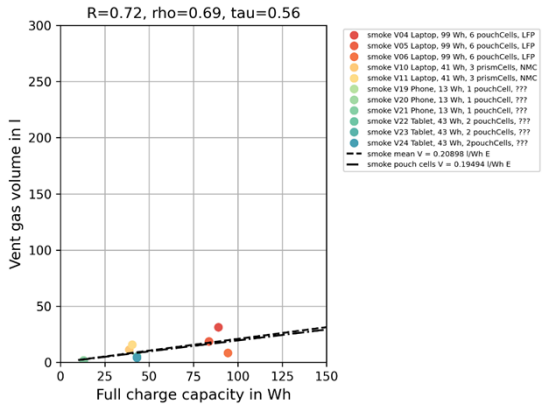
9

9

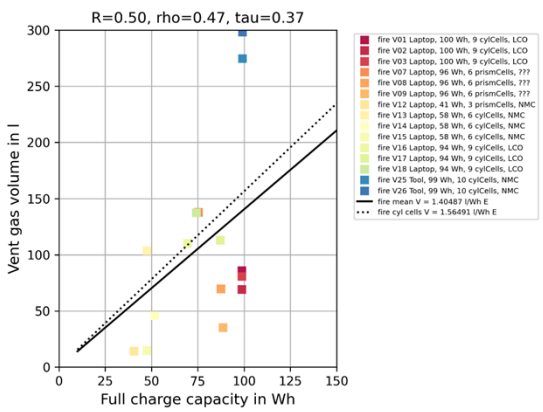
Gas flow - Smoke source model from PED abuse tests

Perspective: per device (sum of all events or peaks)

Smoke



Fire

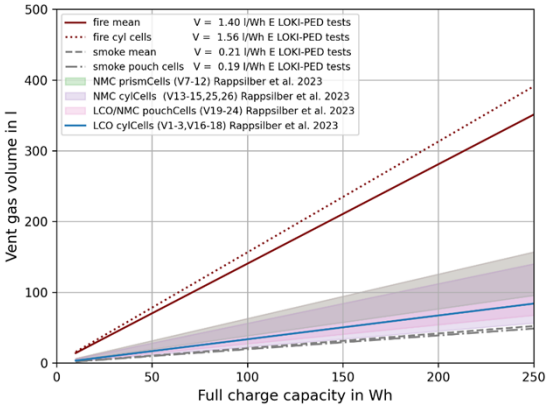


10

Smoke source model from PED abuse tests

Gas flow

Perspective: per device (sum of all events or peaks)



Conclusions:

- Fire hazard increases gas volume compared to smoke hazard
- **Fire hazard** gas volume is larger than pure battery gas volume, combustion increases gas volume.
- **Smoke hazard** gas volume is in same order of magnitude than in literature.
- Main contribution from battery, little from plastics.
- Scaling with energy content:
  - Assumption: Linear increase of emissions with Wh
  - Linear fits enable extrapolation for larger Wh for risk assessement.
  - Note: Future battery technology might behave totaly different.

11

Test set-up for WP2.2 – A320 mockup test

Cabin fire

A320 mockup

9 Tests performed without human intervention, at 4 positions, with realistic ventilation conditions, and PED in thermal runaway

EASA

12

12

Smoke spread in single aisle cabin without human intervention

Cabin fire

A320 mockup

Air ventilation pattern in a single-aisle cabin, here an Airbus A320 – modified

Seite 13

LOKI-PED

Fraunhofer

13

Laptop in the floor (Smoke spread in single aisle cabin without human intervention)

Cabin fire

A320 mockup

LOKI-PED

Fraunhofer

14

Laptop in the overhead bin (V34)

Cabin fire

A320 mockup

- Measurements made for the characterization.

LOKI-PED

Fraunhofer

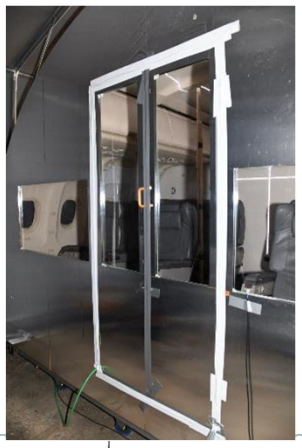
15

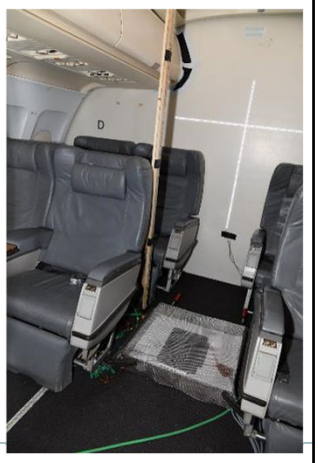
CONCLUSIONS Characterization of main hazards posed by PEDs

PED abuse tests performed in the chamber and in the A320 mock-up to do **characterisation and determine patterns, smoke components, and visibility**.

Conclusions:

- More volume of gas in fire events than smoke events
- Smoke from casing not relevant compared to the smoke from the battery
- Toxic smoke released: crews should protect themselves from smoke
- Events have to be dealt with asap (otherwise, catastrophic)





EASA LOKI-PED Fraunhofer 16

16

Experimental Approach – Smoke spread and handling in wide-body cabin

Flight Test Facility
06/2024 & 03/2025

WP 2	**Smoke spread in cabin** as reference for simulations
WP 5	**Influence of air ventilation** on smoke spread **Where to place the PED** during/after TR w/o bag, gloves

Flight Test Facility, Fraunhofer IBP

Seite 17

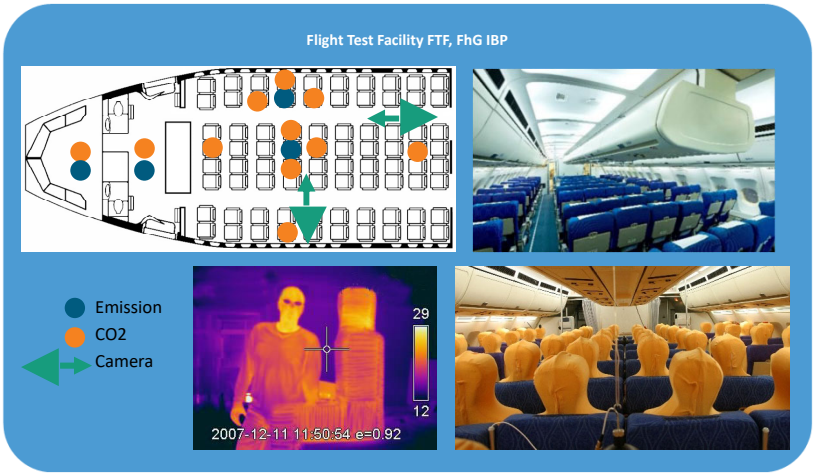
LOKI-PED Fraunhofer

17

Full scale cabin test – set-up for the cabin

72 +2 heated dummies, 75W each
Use of theatre smoke and tracer gas
- **Visual spread of gas**
- **Measured spread of gas**

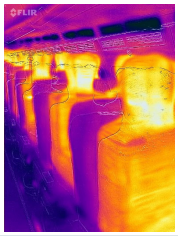
Variations
- **Ventilation** scenarios
  - Normal flow per PAX: 0.55 lb./min. fresh
  - Flow, incl. Recirculation: +50% recirc
  - Normal flow with gaspers
- **Emission locations**
  - Below seat 4F & 4H
  - Overhead locker closed 4H, short intermediate small opening (simulate extinguisher discharge) and closing
  - Newspaper holder 4F & 4H
  - Galley
  - Cockpit

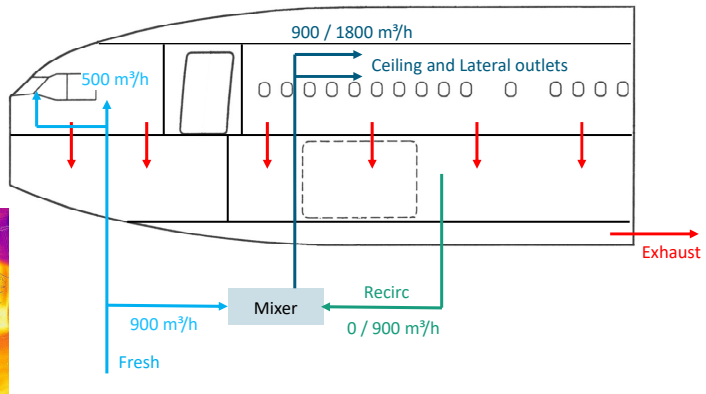


18

Ventilation flow pattern in the cabin

- Cabin Fresh: ~900 m³/h → 3.5 l/s for 72 passengers
- Cabin Recirc: 0 or ~900 m³/h (50%)
- Cockpit Fresh: ~500 m³/h





19

Observations for cabin emission tests

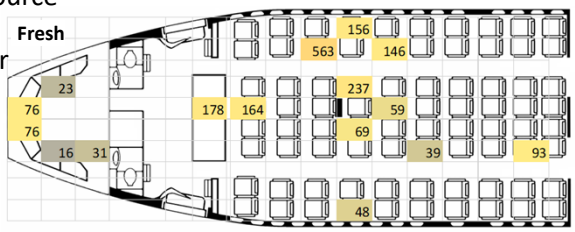
Elevated concentrations found 1-2 seats away from source

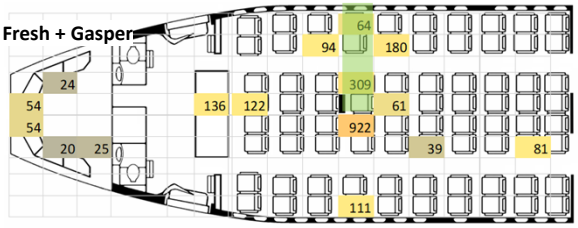
No major overall difference for cabin exposure with or without recirculation

Double exposure in galley without recirculation
→ unventilated in test

- Side flow paths may overflow to galley
- Recirc draws air downwards from cabin → effect weakened when disactivating recirculation

Gaspers show to redirect the peak (4HK lowered, 4E increased)





EASA LOKI-PED Fraunhofer 20

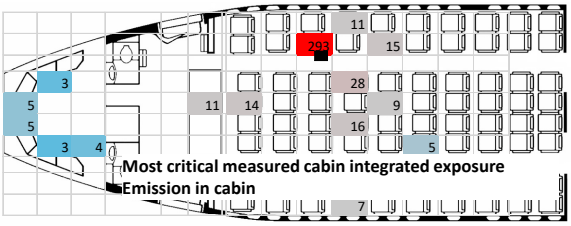
20

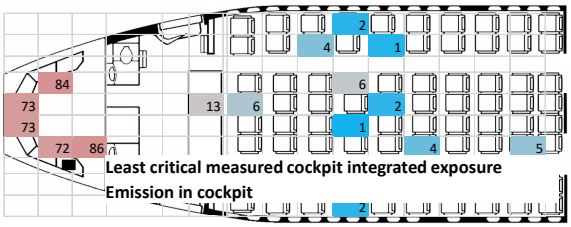
Conclusion Cockpit and Galley emission results

Compared to cabin, the emission test in cockpit and galley shows higher CO2-concentrations

With / without recirculation shows to alter flow balance of galley flowing towards cabin / cockpit → to be considered for full-size aircraft to avoid overflow to cockpit

Emission in cockpit shows only low impact on cabin (with and without recirculation)





EASA LOKI-PED Fraunhofer 21

21

Assessment of exposure to noxious gas

Measurement of combustion gas composition (in the chamber) to determine the correlation between CO_2 emission and smoke and noxious gases - Combustion produces harmful gases such as Carbon monixide (CO), Formaldehyde (CHCO), and Hydrogen flouride (HF))

Main combustion product is carbon dioxide (CO_2), which is easy to measure and track and safe to use in experiments.

Visibility reduction due to smoke – tests in the A320 mock-up (realistic ventiation pattern) and accurate gas analysis

3D simulation model validation and deduction of the spread radius by testing the CO_2 spread from the PED emulator in the mock-up.

Test Box

A320 mockup

LOKI-PED

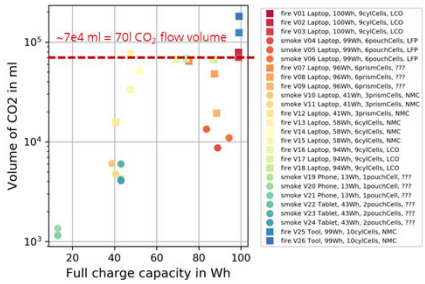
Fraunhofer

Derivation of characteristic CO_2-emission from PED fire

CO_2 emission results from burn chamber tests

- Selection made to consider laptop fire
- Approx. 70l CO_2 emission for a PED thermal runaway

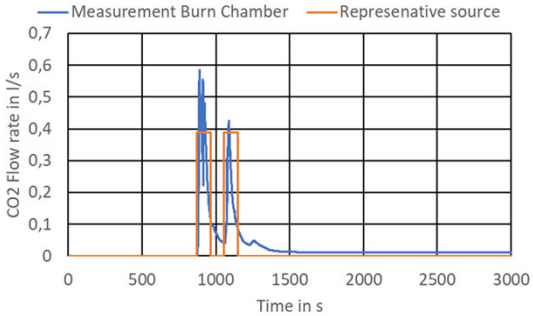
CO2 volume from battery and combustion



Typical CO_2-Emission profile during two consecutive ignitions

Deduction of representative CO_2-source for simulations

- 90s fire & smoke
- 90s rest
- 90 s reignition



LOKI-PED

Fraunhofer

Correlation of noxious gases to CO_2 emission

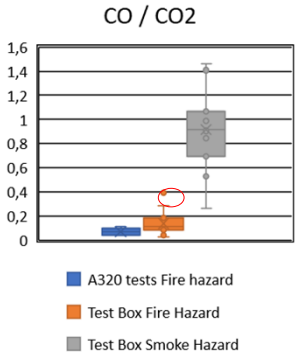
1. Deduction of peak CO_2 concentration vs. other peak concentration of other measured substances in
   - A320 mock-up for fire hazard
   - Test box for fire hazard
   - Test box for smoke hazard

$$f_i = \frac{c_{i,peak}}{c_{CO2,peak}}$$

2. Derivation of 10-min AEGL-2 (acute exposure guideline levels)
   - Serious or long lasting health effects or impairment to escape
   - Example: 10-min AEGL-2 for CO is 420 ppm

3. Derivation of critical associated CO2-level

$$c_{CO2,crit} = \frac{c_{10minAEGL-2}}{f_i} = \frac{420ppm}{0.39} = 1078ppm$$

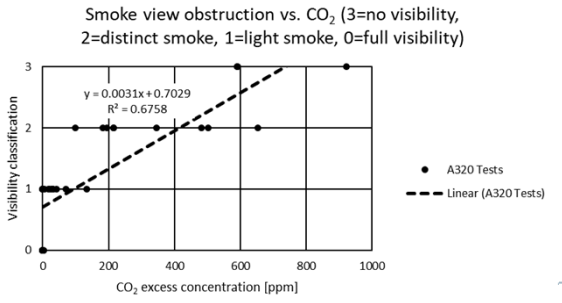


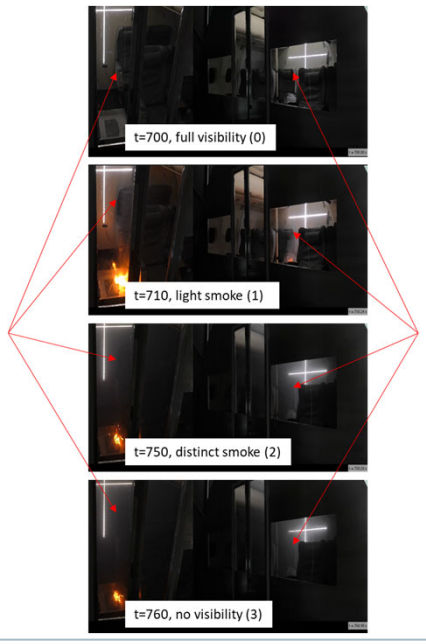
Worst case example: for 70l CO_2 produced in combustion, up to 27.3l of CO is produced

Note: During smoke event much lower volume of CO_2 is emitted and therefore less CO is emitted even though relative fraction is higher.

Correlation of visibility to CO_2 emission

1. Review of videos from A320 mock-up burn tests
   - Visibility of rear row backrest as criterion for smoke density (0: full visibility, 1: light smoke visible, 2: impaired visibility due to smoke, 3: no visibility)
2. For each of the levels and timesteps: read out CO_2-concentration in exhaust gas measurement
3. Plot data visibility vs. CO_2 concentration
4. Draw correlation line

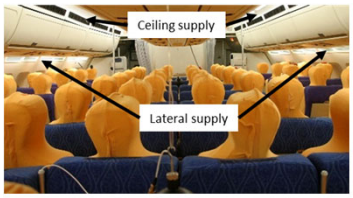


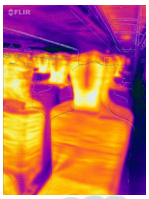


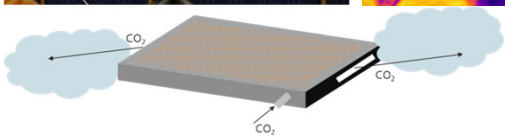
Experimental series: CO2 emission through a PED emulator in Flight Test Facility Cabin Demonstrator

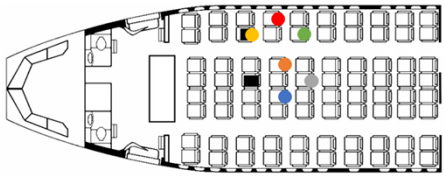
Experimental study using a PED-emulator

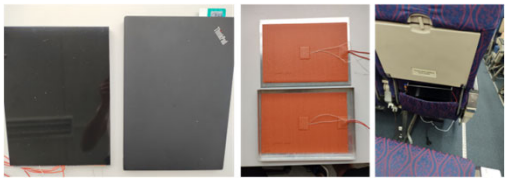
- Emission of CO_2 in different locations (variation of seat, newspaper holder vs. floor, overhead bin)
- Variation of flow pattern (with / without recirculation, use of gaspers)
- Measurement of CO_2-distribution
- Validation of cabin spread simulation model











26

LOKI-PED

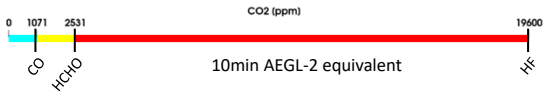
Fraunhofer

26

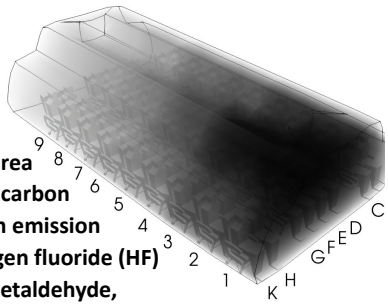
Simulation example: PED fire in seat 4F, newspaper holder - Cabin fresh air

Simulation of CO_2 spread in cabin

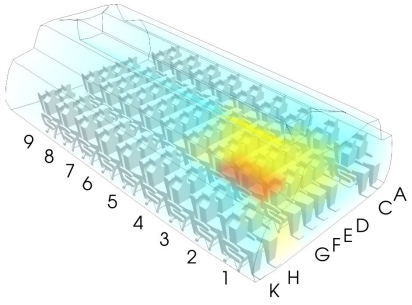
- CO_2 injection according to characteristic profile
- Assessment of peak concentration vs. hazardous substances concentration limit
- Assessment of transient decline vs. hazardous substance time limit
- Deduction of smoke density



Peak smoke spread



Peak concentration in the emission zone



Result

- **Peak excess of 10min AEGL-2 for formaldehyde (HCHO) in emission area**
- **Short-term excess of 10min AEGL-2 for carbon monoxide (CO) in approx. ±2 seats from emission**
- **No reaching of 10min AEGL2 for hydrogen fluoride (HF) and other substances assessed (HCl, Acetaldehyde, Methanol)**

27

LOKI-PED

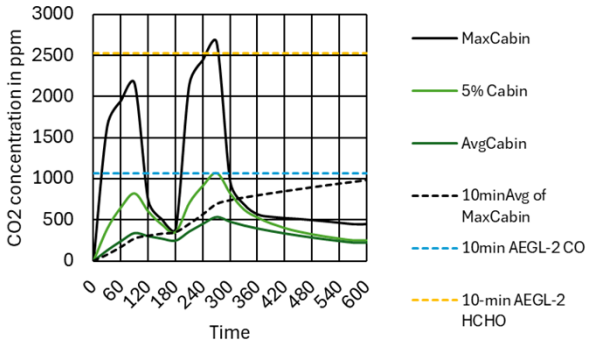
Fraunhofer

27

Transient exposure evolution

Evaluations
- Maximum concentration in entire cabin…
- …down to lower limit of 5% highest concentrations in entire cabin
- Average concentration in cabin

Results for Exposure
- **Maximum concentration has short-term exceedance of 10min AEGL-2 for CO and HCHO, but 10min average remains below**
- **Only 5% of cabin volume temporarily exceeds 10min AEGL-2 for CO, i.e. 95% remain below**



LOKI-PED

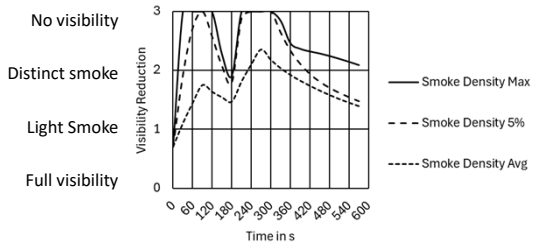
Fraunhofer

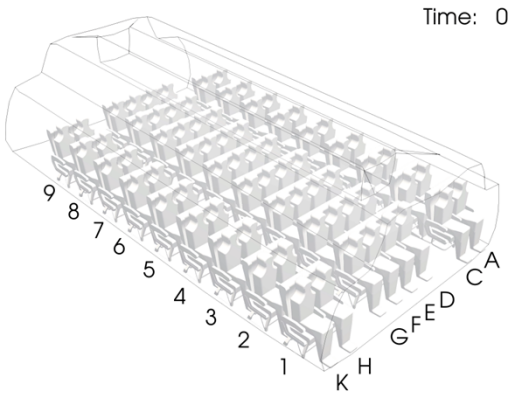
28

Transient smoke simulation evolution

Results for smoke
- First incident:
  - 5% of cabin have short-term no visibility (approx. 1 minute)
  - Average cabin sees between light and distinct smoke
- Second incident:
  - Average cabin sees distinct smoke that clears within approx. 1-3 minutes

→ Action should be taken to prevent 2nd thermal runaway propagation





LOKI-PED

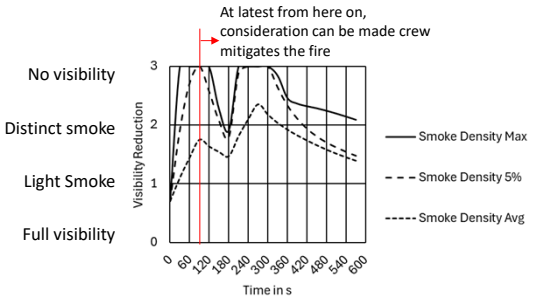
Fraunhofer

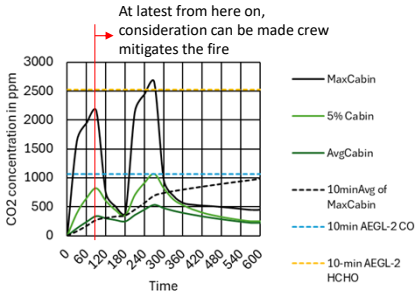
29

Assessment of injection profile vs. reality

Project partner Airbus performed review of clips and experiments

- 90s burning can be estimated as the worst-case scenario found
- After 90s, fire is extinguished by crew and second peak should not occur → Second peak reflects a non-treated fire event





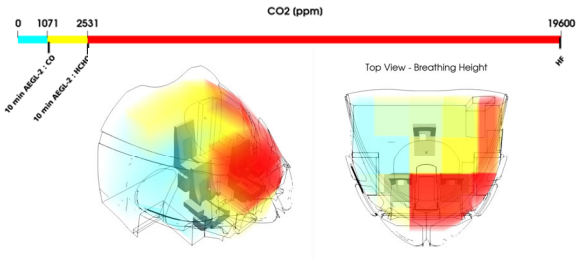
LOKI-PED

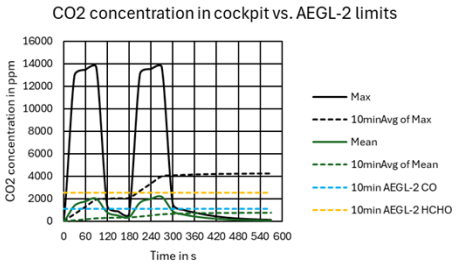
Fraunhofer

30

Assessment of exposure from burning 100Wh notebook in cockpit

- Maximum concentration location:
  - Already within 1min, the 10min-average AEGL-2 level for CO is exceeded → serious harm to pilots possible
  - During the first ignition, the 10min-average AEGL-2 level for HCHO is approached → only thin margin (especially considering this is a model case)
- Average concentration approaches 10min-average AEGL-2 level for CO
- Pilots should use PSE or full cover oxygen masks with independent air supply to avoid breathing the ambient air
- Quick action to extinguish / remove the PED is crucial





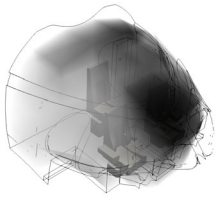
LOKI-PED

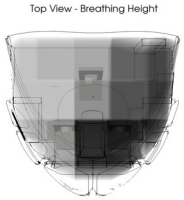
Fraunhofer

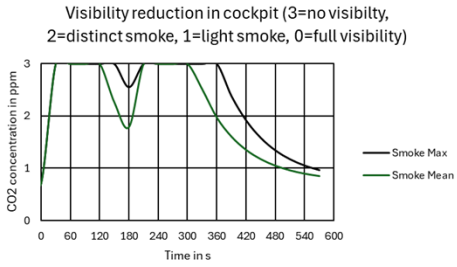
31

Assessment of smoke from burning 100Wh notebook in cockpit

- Already within 1min, visibility is clearly impaired and only starts to restore after another 2 min
- If a second fire emerges, visibility is again reduced
- Quick action should be taken to extinguish fire and remove the PED from the cockpit







LOKI-PED

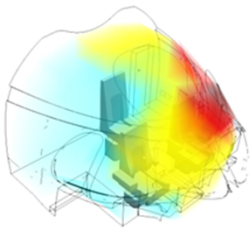
Fraunhofer

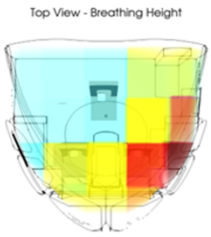
32

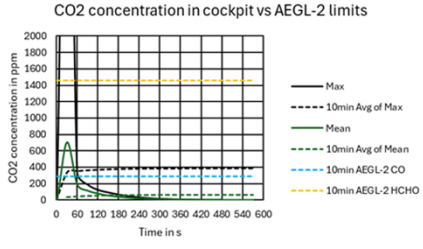
Comparison: Exposure from smoking tablet in cockpit

- Max. concentration exceeds 10min-average AEGL-2 for CO
- Average concentration remains clearly below 10min-average AEGL-2 for CO

- → Restricting cockpit devices to tablets might be a useful means (forbidding 100Wh notebooks)







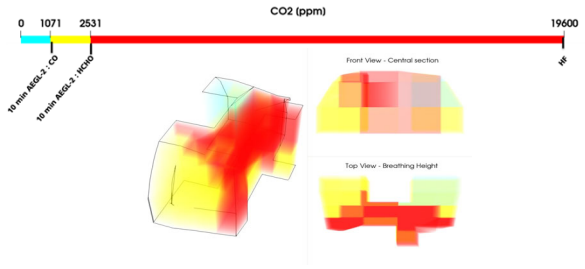
LOKI-PED

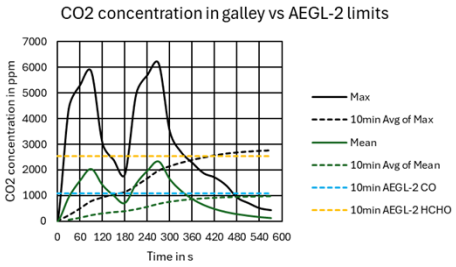
Fraunhofer

33

Assessment of exposure from burning 100Wh notebook in galley

- Maximum concentration location:
  - After first event, the 10min-average AEGL2 for CO is reached
- Average exposure remains below 10min-average AEGL2 for CO during first event and is approached after second event
- → quick action required to avoid second fire event





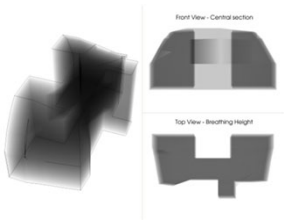
LOKI-PED

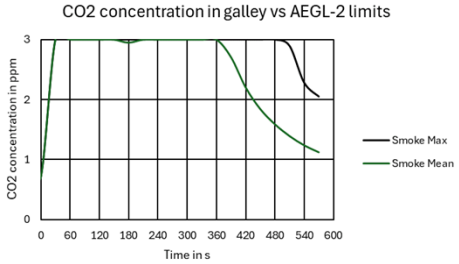
Fraunhofer

34

Assessment of smoke from burning 100Wh notebook in galley

- Galley fills with smoke → reduced visibility expected
- Quick action should be taken to avoid additional smoke production



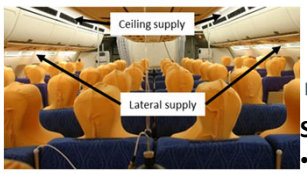


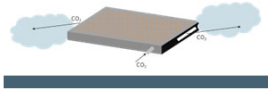
LOKI-PED

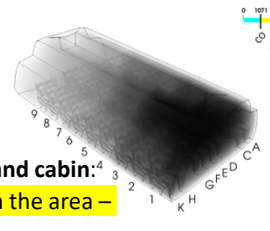
Fraunhofer

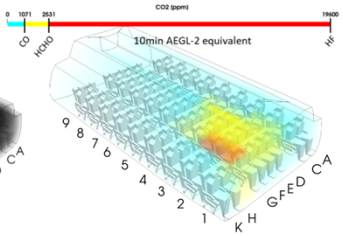
35

LOKI-PED – Smoke Spread Cabin, Galley & Cockpit



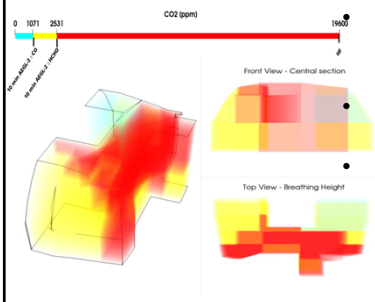


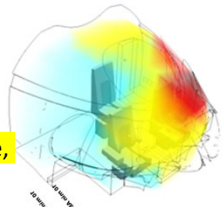


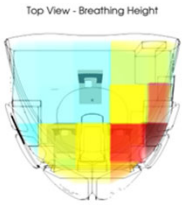


Simulation in cockpit, galley and cabin:

- Pax should be moved from the area – toxic gases released
- Short-term no visibility in 5% of the cabin (aprox. 1 min), clears after 1-3 min.
- Visibility impaired in cockpit and only restores after 3 minutes.
- Serious harm to pilots within 1 minute, they should done masks immediately and PED should be extinguished/removed from the cockpit asap.







LOKI-PED

Fraunhofer

36

Battery Test Center – Fraunhofer EMI

Experimental Approach – PED and battery abuse characterization

→ **Battery Test Center**

→ 08/2023 & 06/2024

WP 6

Containment capability of bags
Cooling capability of extinguishers
Realization: Laptop (100Wh, 9 cylindrical cells)
Selection of bags and extinguishers by working principle
Diagnostics:
- gas volume (source)
- gas composition (toxicity)
- temperature on bag (handling)

EASA

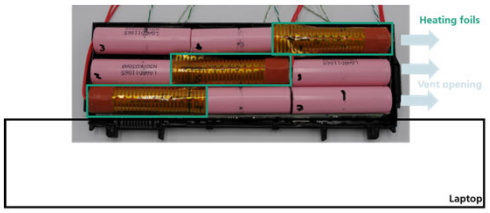
37

37

PEDs to be tested

Status

- 24 refurbished laptops
- New batteries: 11 on site, 13 delivered end of August
  - One order
  - Two shipments with different battery chemistry (new, new 2)



#	Test	Battery cells	Status
1	Characterization 1	9 cells 97 Wh	new
2	Characterization 2	9 cells 97 Wh	new
3	Bag 1	9 cells 97 Wh	new
4	Bag 2	9 cells 97 Wh	new
5	Bag 3	9 cells 97 Wh	new
6	Bag 4	9 cells 97 Wh	new
7	Bag 5	9 cells 97 Wh	new
8	Bag 6	9 cells 97 Wh	new
9	Bag 7	9 cells 97 Wh	new
10	Bag 8	9 cells 97 Wh	new
11	Characterization 3	9 cells 99 Wh	used
12	Extinguisher 1	9 cells 99 Wh	used
13	Extinguisher 2	9 cells 99 Wh	used
14	Extinguisher 3	9 cells 99 Wh	used
15	A320 w/o intervention 1	9 cells 99 Wh	used
16	A320 w/o intervention 2	9 cells 99 Wh	used
17	A320 w/o intervention 3	9 cells 99 Wh	used
18	A320 w/o intervention 4	9 cells 99 Wh	used
19	A320 w/o intervention 5	9 cells 99 Wh	used
20	Characterization 4	6 cells 66 Wh	used
21	A320 w/o intervention 6	9 cells 97 Wh	new 2
22	A320 w/o intervention 7	9 cells 97 Wh	new 2
23	A320 w/o intervention 8	9 cells 97 Wh	new 2
24	A320 w/o intervention 9	9 cells 97 Wh	new 2

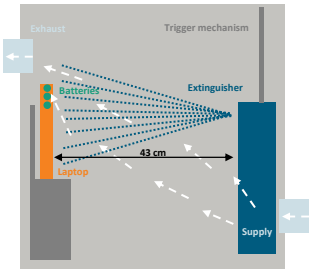
Cool down capability of extinguishers
Summary

Tested extinguishers
- Manufactures from Europe and US
- 3 of 3 especially for lithium battery fires
- 3 of 3 do not contain halon
- 3 of 3 commercially available
- 2 of 3 in service on aircraft

Test conditions
- Laptop with 9 cylindrical cells (100 Wh)
- One cell heated to enforce thermal runaway
- Extinguisher In operation when flames are observed until it is empty
- Extinguishers are empty after 15s to 45s

Findings
- 1 of 3 supressed thermal propagation
- 3 of 3 suppressed flames during operation

Temporal characteristics
- Duration of operation varies
- Multiple events possible
- 2 to 5min from first to next observed



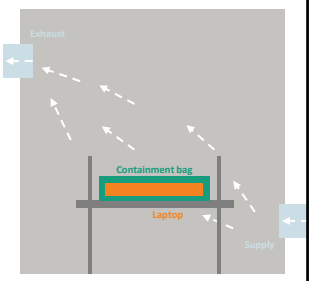
Containment capability of bags
Summary

Tested bags
- Manufactures from Europe and US
- 2 of 8 bags in early design stage
- 6 of 8 commercially available
- 3 of 8 in service on aircraft

Test conditions
- Laptop with 9 cylindrical cells (100 Wh) packed in bag
- One cell was heated to enforce thermal runaway
- Adopted from UL 5800 standard

Hazards observed
- Thermal propagation from cell to cell: 8 of 8
- Venting of smoke: 8 of 8
- Venting of hot particles: 8 of 8
- Venting of flames: 5 of 8
- Opening of bag closure: 2 of 8
- Destruction of bag: 2 of 8

Temporal characteristics
- Duration highly variable
- Multiple events possible
- 1h from first to last event observed



LOKI-PED

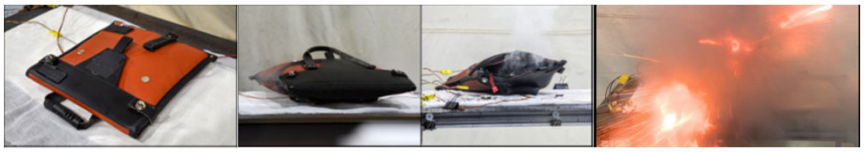
Fraunhofer

40

To compare – FAA activities on FCB testing
DOT/FAA/TC-24/39: An Evaluation of FireContainment Products for InflightFires Resulting from PortableElectronic Devices (PEDs), December 2024

FCBs tested by the FAA are different than in LOKI-PED

- Venting of smoke: 4 of 5
- Venting of hot particles: 1 of 5
- Venting of flames: 2-3 of 5
- Opening of bag closure or rupture: 2-3 of 5



LOKI-PED

Fraunhofer

41

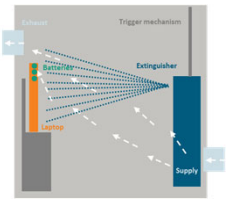
Assessment of mitigation means and procedures

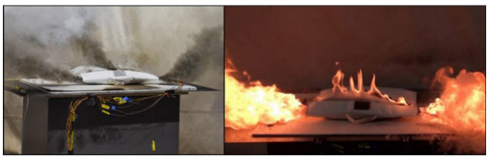
Test of extinguishers and bags for effectiveness

- Extinction after provoking thermal runaway
- Storage in bag when runaway is provoked

Conclusions

- Standard is needed for the container and the firefighting gloves
  - Fire extinguishers fight the immediate fire, but do not prevent event propagation
  - Most containment products showed smoke and some flame emissions
  - Containment products do not inhibit thermal runaway propagation
- EASA maintains position: containment means should NOT be used for firefighting. If carried on board, they can be used after the event is over, for cooling.





Risk assessment

The Consequences depend on e.g. toxic gas concentration and spread (exposure)

Risk = Probability * Consequences

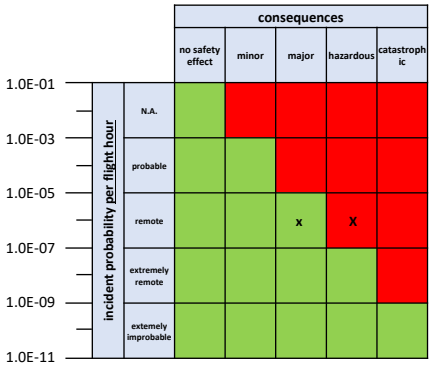
Probability of a thermal runaway event depends on e.g. passenger behaviour / number of items on plane

Risk assessment

Risk
- visualized and classified in form of a risk matrix, which:
→ follows EASA Certification Specification for Large Aeroplanes (CS-25 Amendement 28)
→ establishes a logical and acceptable inverse relationship between the average probability per flight hour and the severity of failure condition effects

- risk regarded as acceptable (green) or not acceptable (red)
→ classification / acceptability based on CS-25 Amendement 28

- risk assessment based on worst credible case, not on hypothetical extremes



LOKI-PED

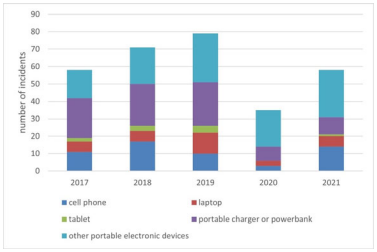
Fraunhofer

Data availability

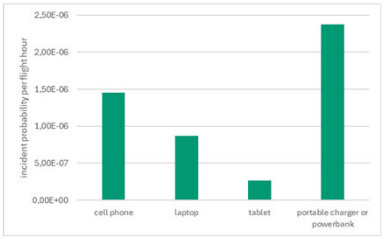
Probability

Data on incident probability
- Expressed as a statistical probability (based on historical event data)
- In general: available data is very scarce and incomplete
  - only absolute numbers
  - no reference to underlying number of flights, airtime or passenger number
- TRIP* database (Most comprehensive source currently available)
  - participating airlines are known
  - supplementary information can be retrieved from the U.S. Bureau of Transportation Statistics
    - number of passengers
    - total airtime
    - number of departures
  - knowing the number of thermal incidents by PED type & supplementary information allows to estimate an incident probability per flight hour

** Thermal Runaway Incident Program*
*** 194 PAX & 4 cabin crew*



Number of thermal incidents by type and year for the years 2017-2021. The data is based TRIP including incident data reported by the FAA.



*Incident probability by PED type on an Airbus A320neo** per flight hour. The estimation is based on the maximum passenger capacity (including the cabin crew).*

LOKI-PED

Fraunhofer

Data availability
Consequences

Data on consequences

- based on experiments and simulations conducted within the LOKIPED project (100 Wh laptop)
- Textual and tabular description of classifications leaves a lot of room for interpretation
- preliminary interpretation of simulation results:
  - AEGL-2 threshold for CO is not exceeded, especially if reignition can be prevented and passengers in the affected area are relocated
    → classification as **»major«**
  - elevated concentrations in the immediate plume may still pose a significant threat to crew members involved in locating, extinguishing, or removing the device, as well as to passengers in the direct vicinity
    → classification as **»hazardous«**
  - serious burn injuries are possible for passengers in close proximity (especially the owner of the PED) to the device or for crew members involved in fire suppression
  - → classification as **»hazardous«**

Figure 2a: Relationship Between Severity of the Effects and Classification of Failure Conditions

Severity of the Effects						
	Effect on Aeroplane	No effect on operational capabilities or safety	Slight reduction in functional capabilities or safety margins	Significant reduction in functional capabilities or safety margins	Large reduction in functional capabilities or safety margins	Normally with hull loss
	Effect on Occupants excluding Flight Crew	Inconvenience	Physical discomfort	Physical distress, possibly including injuries	Serious or fatal injury to a small number of passengers or cabin crew	Multiple fatalities
	Effect on Flight Crew	No effect on flight crew	Slight increase in workload	Physical discomfort or a significant increase in workload	Physical distress or excessive workload impairs ability to perform tasks	Fatalities or incapacitation
Classification of Failure Conditions		No Safety Effect	Minor	Major	Hazardous	Catastrophic

CS-25 Amendment 28 (page 866)

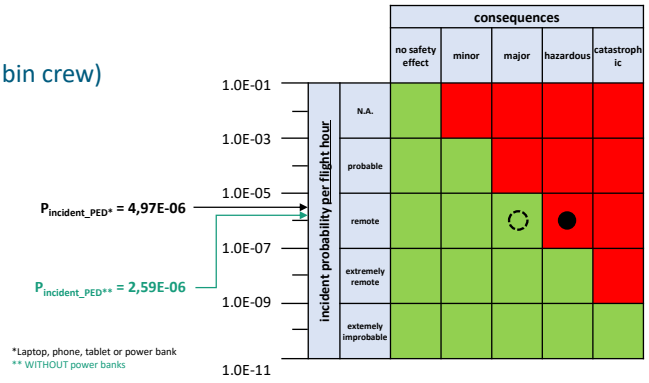
Preliminary Conclusion
A320neo sized aeroplane (i.e. 194 passengers + 4 cabin crew)

Preliminary Conclusion

- Toxic gases: Thermal runaway of a PED is classified as **»hazardous«** due to direct handling without guaranteed respiratory protection or immediate fire suppression. Toxic gas concentrations in the plume pose a significant exposure risk to crew members.
- Fire: Serious thermal injuries to crew members during containment handling fulfill **»hazardous«** criteria

R = P * C

- Even a complete exclusion of power banks would not shift the probability from **»remote«** to **»extremely remote«** under CS-25 Amdt. 28.
- Risk reduction must focus on mitigating consequences, e.g., by implementing effective safety measures.



- Risk reduction must focus on mitigating consequences, e.g., by implementing effective safety measures
- Any changes in the current scenario would shift the consequences from major to hazardous
- Limitations should be put in place for the number of PEDs carried on board and Wh limits should not be increased

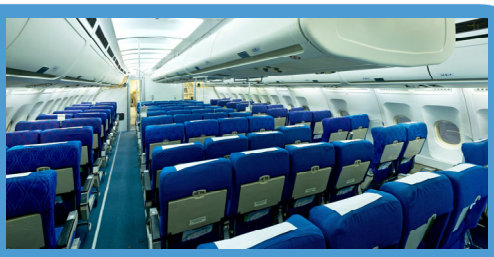
PED Fire mitigation

Flight Test Facility

06/2024 & 03/2025

WP 6

Handling of smoke emitted from PEDs by crew in real cabin with bags, extinguishers and personal protective equipment like gloves and smoke hoods



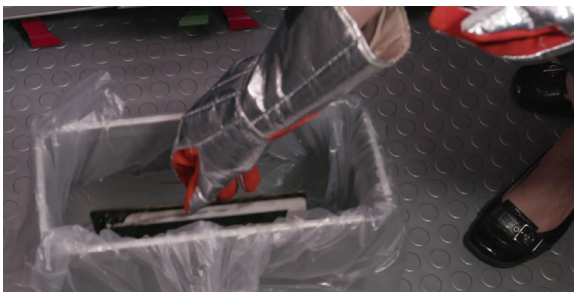
Flight Test Facility, Fraunhofer IBP

Additional Mitigation Means

Identified PED fire mitigation means
- Baseline procedure (similar to FAA videos)
- Dedicated fire extinguishers
- Containment bags

Test of extinguishers and bags for effectiveness
- Extinction after provoking thermal runaway
- Storage in bag when runaway is provoked

Test of bags for handling
- Participation of professional cabin crew members
- Evaluation of baseline procedure and bag handling during a simulated PED fire (with emission of smoke)
- Post-test interview of test participants



PortableElectronicDeviceFireTrainingFlightDeck : FAA Fire Safety

LOKI - Crew test conduct

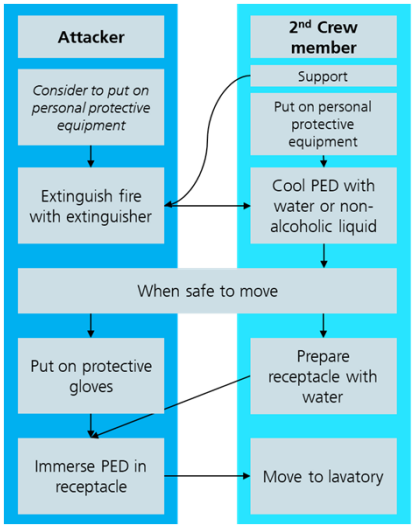
Investigation of
- Baseline procedure
- Pure storage bags
- Kits with extinguishing means and bag
- Bags involving water
- Bags with additional smoke bag around containment bag (not part of fire testing effort)

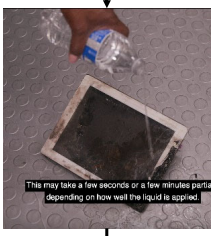
Crew was allowed to use PBE at own choice

Presented scenario
- Smoke + fire for suppression means and storage tests
- Only short smoke emission for pure storage bag tests

Test statistics
- 11 bags, each 3-4 times in use
- 9 airlines participated with 1-3 crew members
- 5 consecutive days of test

Baseline procedure





PortableElectronicDeviceFireTrainingCabin : FAA Fire Safety

Crew feedback on baseline procedure

Crew feedback ☹
- Tradeoff between quick action and self-protection difficult
- Involves many steps, extensive training required
- Bottle cooling
  - Small bottles impractical, opening bottles challenging with gloves
  - Obstruction of the aisle by bottles
  - Long action close to PED required
- Receptacle
  - Obstruction of the aisle
  - Difficult to judge when PED can be moved
- Coordination (hearing) difficult due to cabin noise and PBE (if used)
- Equipment in test was stored close to the fire → should be in safe space

Crew feedback ☺
- Attacker can immediately react and guarantees quick fire extinction
- Opening bottles was possible with gloves
- Once trained easy to coordinate

Recommendations for improvement
- Uncertainty on PBE use
  - Information wished on potential crew exposure
  - Information wished on the threat of smoke/fire during delay time posed by PBE preparation
- Procedure modification
  - Clearly state that unprotected PED extinction must be minimized to the acute fire fighting. Attacker shall asap. leave afterwards
  - Provide clearer definition of roles, evtl. with pictograms
  - Ensure PED remains attended during whole procedure
  - Provide information on the effect of water on cabin / galley / cockpit floor and health concerns (crew is reluctant to pour water)
- Receptacle
  - Provide examples of suited receptacles depending on PED size
  - Extend procedure with specification that water is poured onto PED in receptacle (ensures better immersion and avoids floating)
  - Some airlines carry dedicated plastic boxes
- Some airlines carry dedicated (larger) water bottles

LOKI-PED

Fraunhofer

52

Crew feedback on bags

Bag recommendations
- Bag packaging should easily open
- Bags should be ready to use (no additional mounting)
- Bags should be intuitive and e.g. not require 90° rotation from packaging to opening
- When opened, bag should not close by itself but remain open
- Bags should be large enough to host typical PEDs; analogous for smoke containment bags
- PEDs should fit both ways (long and short side)
- Zippers
  - Should have handle to ease operation with gloves
  - Should not block
- Bucklets more difficult than zipper
- Unalignment of Velcro closure should not occur (make Velcro strips wide enough to align)
- Bag openings should be indicated by visual element
- PED should be secured in bag to not fall out during handling
- Handle on bag for transport preferable

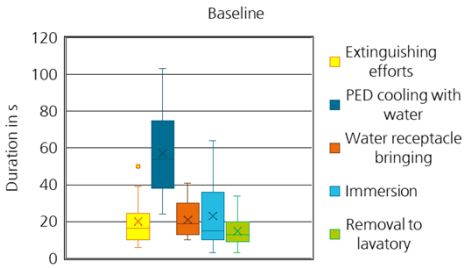
Recommendations for procedures
- **Two-person operation of bags usually required** → consider having two pairs of gloves with the bag instead of one
- Available space in cabin aisle should be considered
- Good and visual documentation of bag procedure should be available including
  - When shall bag be used
  - How shall it be used
  - What to do when PED is in bag
- Bag should not add workload in pre-flight check; each component's state should be visible

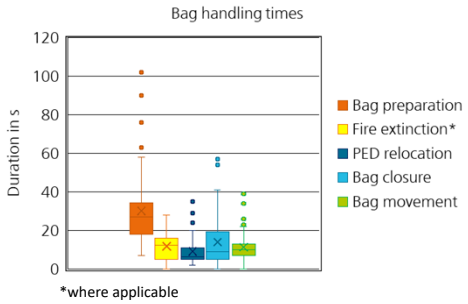
LOKI-PED

Fraunhofer

53

Estimated duration of operation steps





*where applicable

LOKI-PED

Fraunhofer

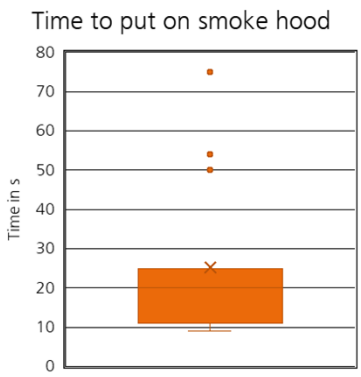
54

PBE usage interview

Reasons for crew to wear PBE
- Crew is trained to use as soon as smoke is visible
- Impaired sight, large amount of smoke
- When hard to breathe
- Smell event
- Feeling of need to protect oneself

Reasons for crew to take off PBE
- Individual judgement
  - When hard to breathe or uncomfortable
  - When operation is done, and crew returns to galley
  - When out of area and crew returns to galley
  - Smoke is gone and situation cleared
  - If communication requires
- Objective
  - After time taking (1 airline only mentioned this)
  - Red flash indication on some smoke hoods

Time was taken when crew used smoke hood



LOKI-PED

Fraunhofer

55

LOKI-PED Assessment of mitigation means and procedures

Test of bags for handling - summary

- 9 airlines volunteered 1-3 CC who participated during 5 days in the tests done at the Flight Test Facility
- Observation of baseline procedure (same as video of the FAA) and bag handling during an emulated PED fire or smoke (emission of theatre smoke)
- Special consideration given to the use of PBE – data will be used in the revision of EASA's SIB
- Post-test crew interview – feedback considered for the amendment of the ICAO Doc 9481 Emergency Response Guidelines for Aircraft Incidents Involving Dangerous Goods

Conclusions:

- If crew member judges not to wear PBE to attack quickly:
  - Limit exposure to acute fire fighting
  - Asap replace by protected colleagues
- Improvements to be made to the containment bags
- Handling of bags should be done by two CC
- Improve ERG procedures with the input provided

PortableElectronicDeviceFireTrainingFlightDeck : FAA Fire Safety

EASA
European Union Aviation Safety Agency

Any Questions ?

easa.europa.eu/connect

Your safety is our mission.

An Agency of the European Union