PYROGEL

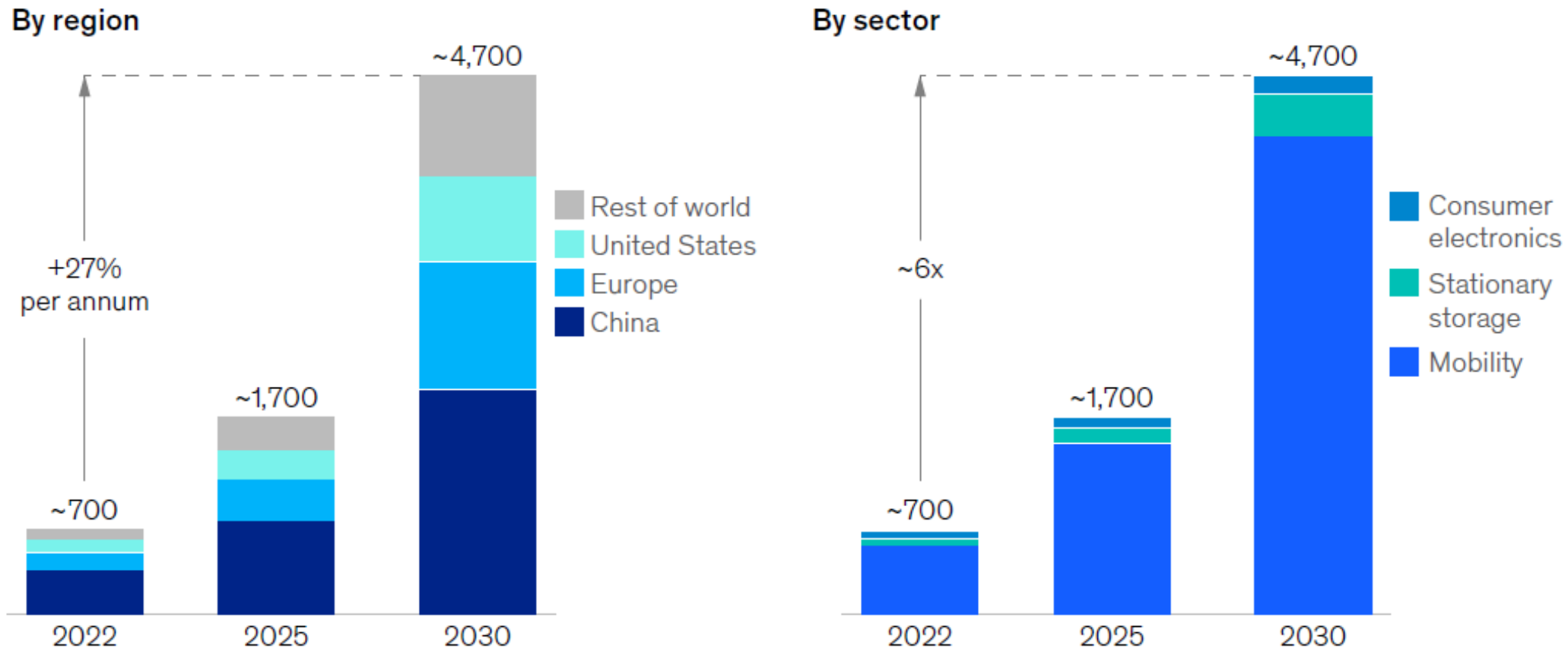
Revolutionary Battery Fire Extinguishant

Ir. Dr. Andrew Ng
CTO, Pyro X

Exhibit 1

Li-ion battery demand is expected to grow by about 33 percent annually to reach around 4,700 GWh by 2030.

Global Li-ion battery cell demand, GWh, Base case



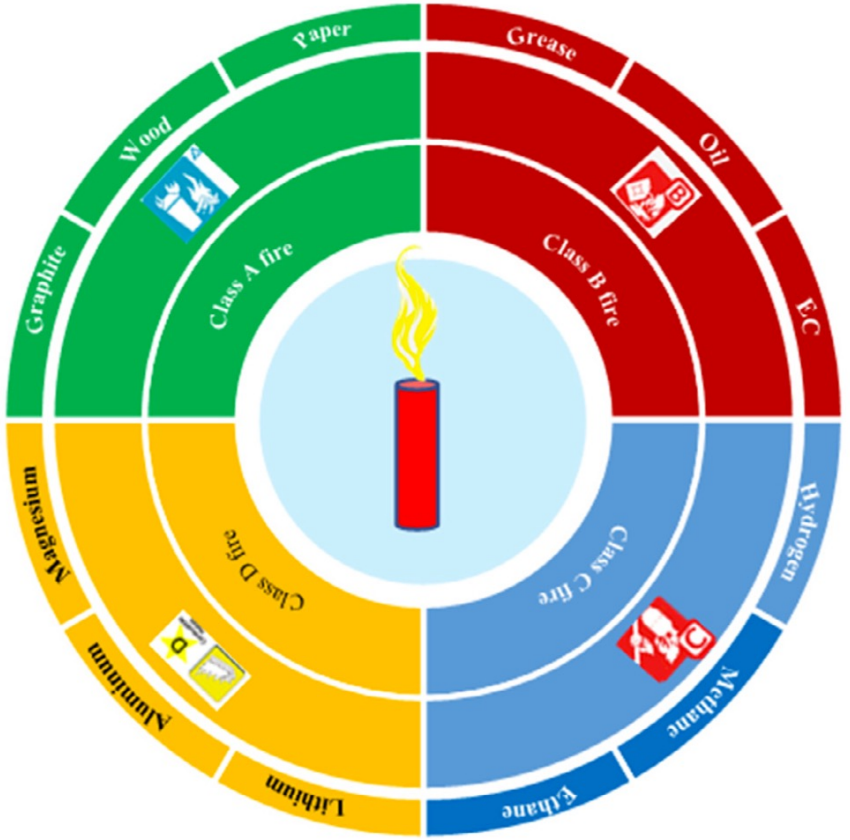
[1]Including passenger cars, commercial vehicles, two-to-three wheelers, off-highway vehicles, and aviation.
Source: McKinsey Battery Insights Demand Model

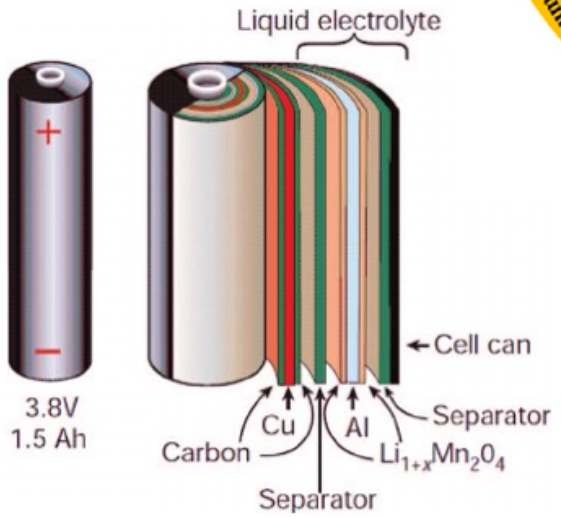
LiB fire hazard

Multi-fire class

No fixed classification of fire class as of now for
Lithium-ion battery (LiB) fire due to its multi-component fire sources

Class A: Polymeric separator, Graphite anode
Class B: Electrolyte liquid, fluoride solvents
Class C: Flammable hydrocarbon vapors
Class D: Lithium metal oxide cathode/Li dendrites
Class E: Electrically energised





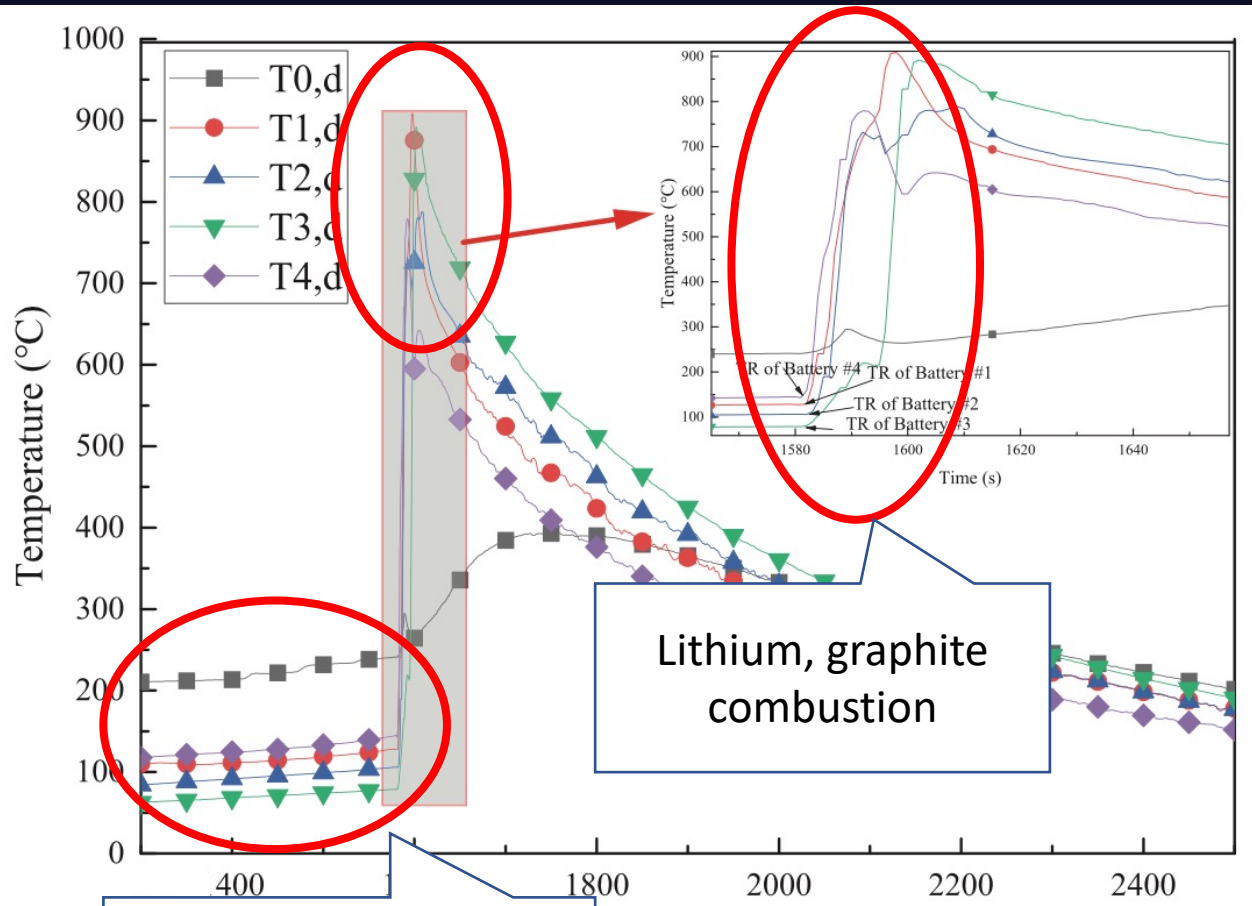
Yuan et al., **2021**, *JEC,* 62:262-280

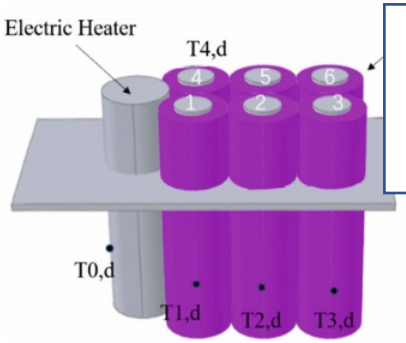
LiB fire hazard

Fast and furious

A study by Beijing Institute of Technology and Tsinghua University on LiB thermal runaway

1. Very high temperature (600-900 °C)
2. Very fast runaway (~800 °C in 20 s)
3. High combustion energy (~2,596 kcal/kg)

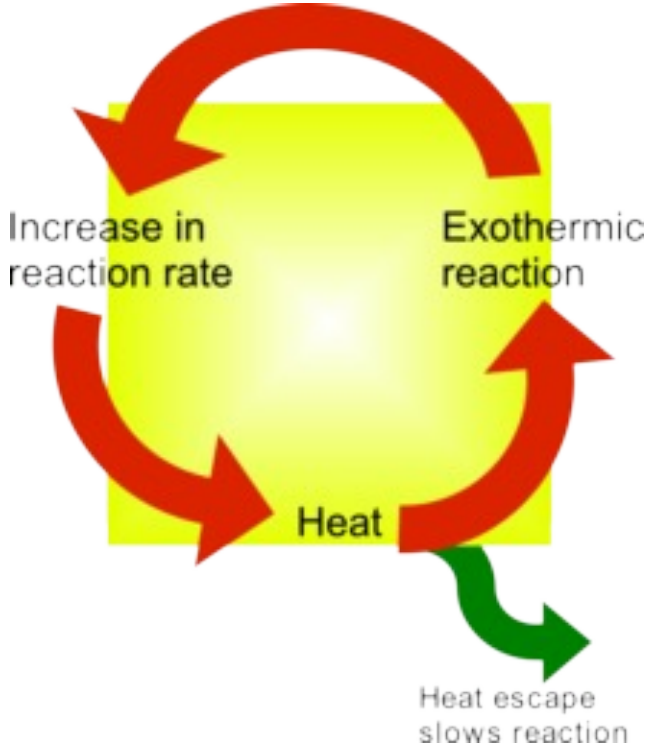




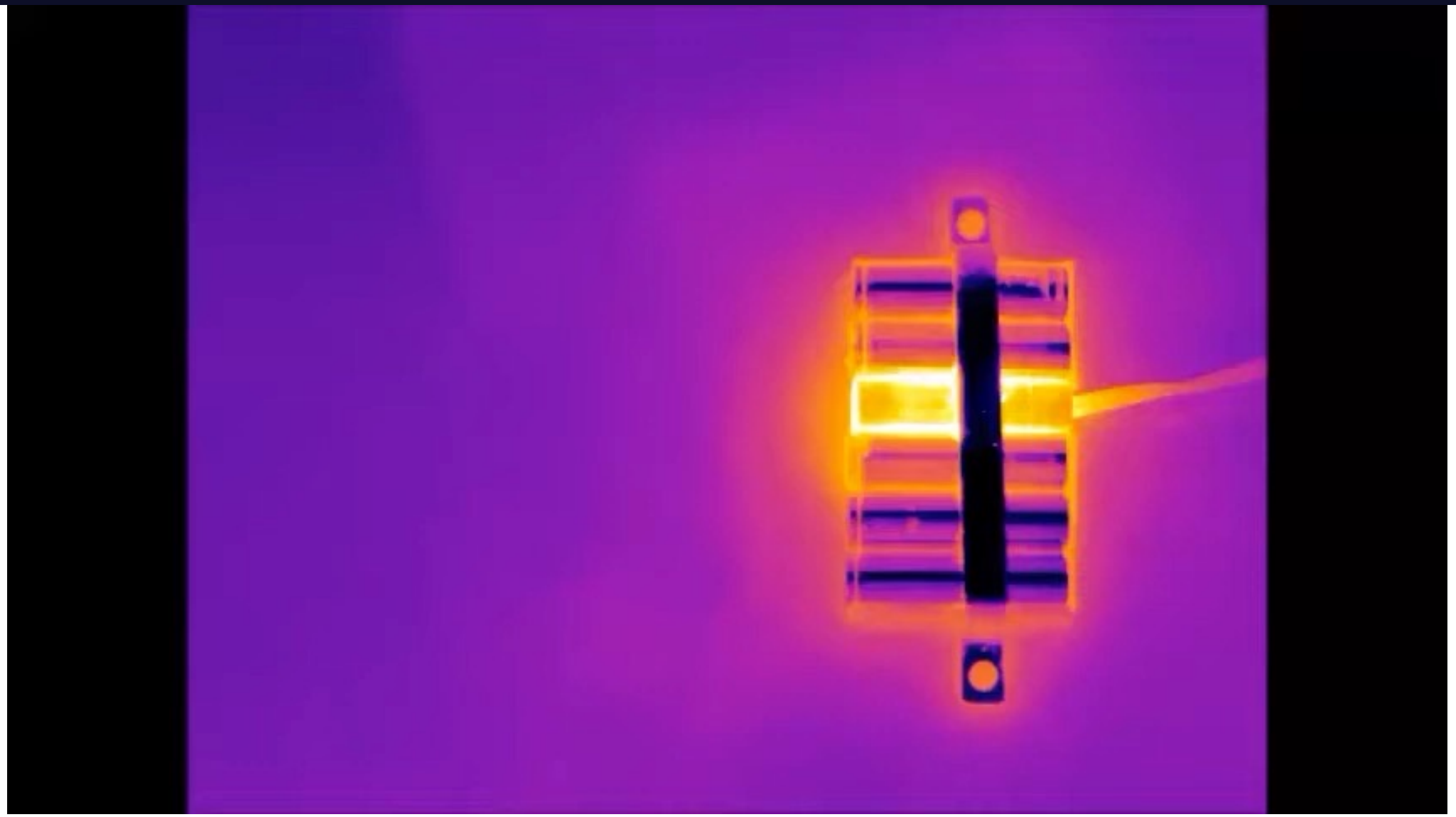
Yuan et al., **2022**, *JES*, 55:105186
Ping et al., **2015**, *JPS*, 285:80-89

LiB fire hazard

Thermal runaway



Source: evfiresafe.com



Source: George Brilmyer

Fire Tetrahedron

Battery fire's complexity

1. Self-sustained oxygen source

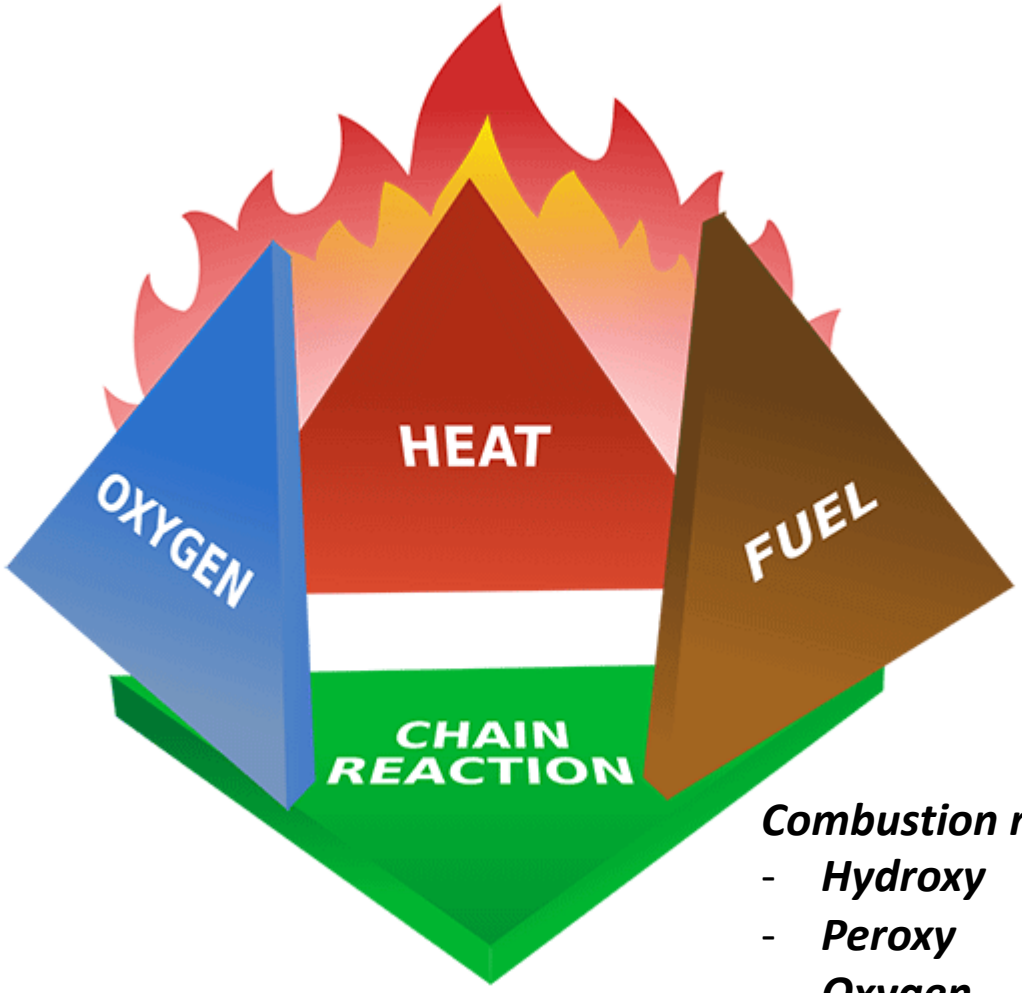
   (Lithium metal oxides)

2. High heat

   (Thermal runaway)

3. Various fuel sources

4. Complex chain reactions

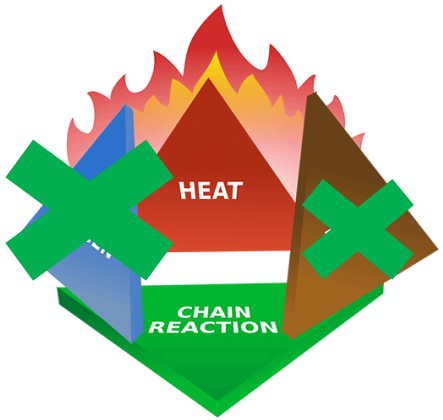


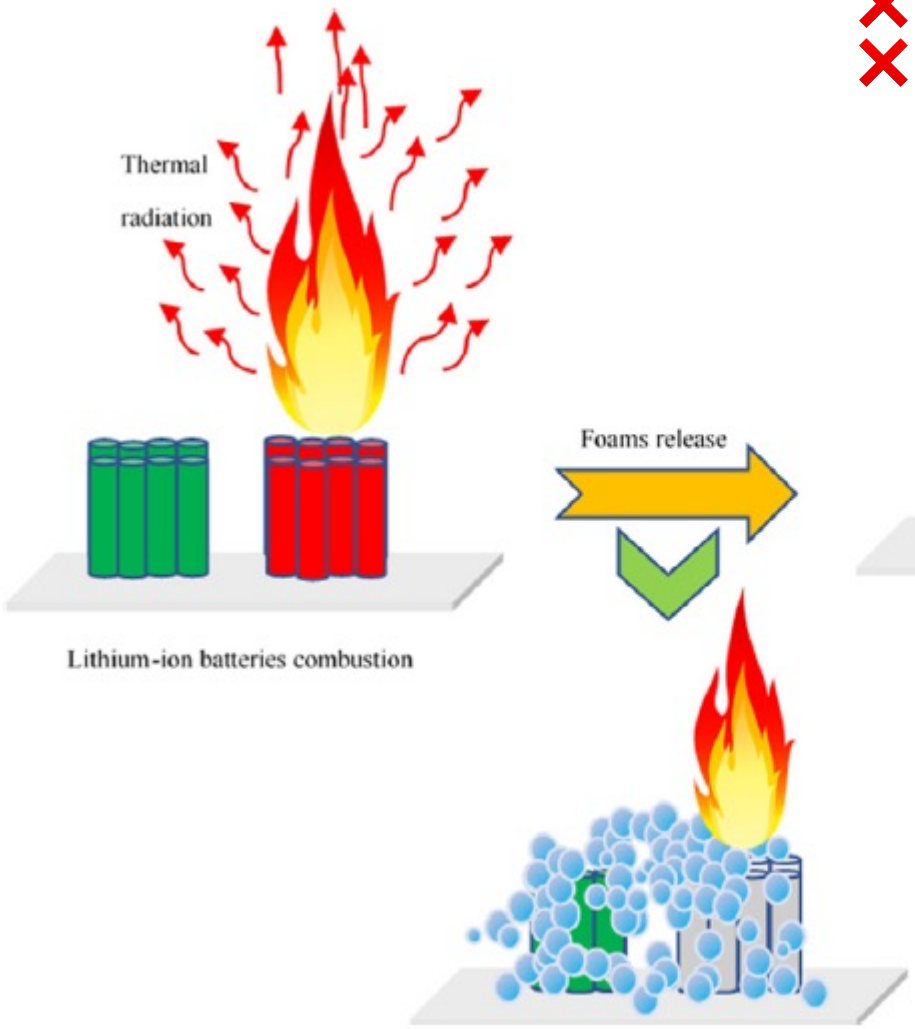
Combustion radicals

- ***Hydroxy***
- ***Peroxy***
- ***Oxygen…..***

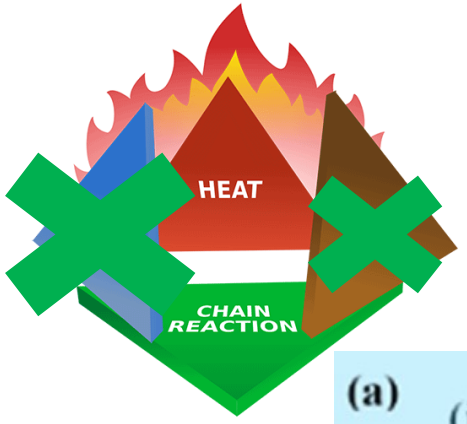
Technique comparison (Foam)

- ❌ Not suitable for self-sustaining oxygen source
- ❌ Surface extinguishment
- ❌ Carcinogenic (PFAS)

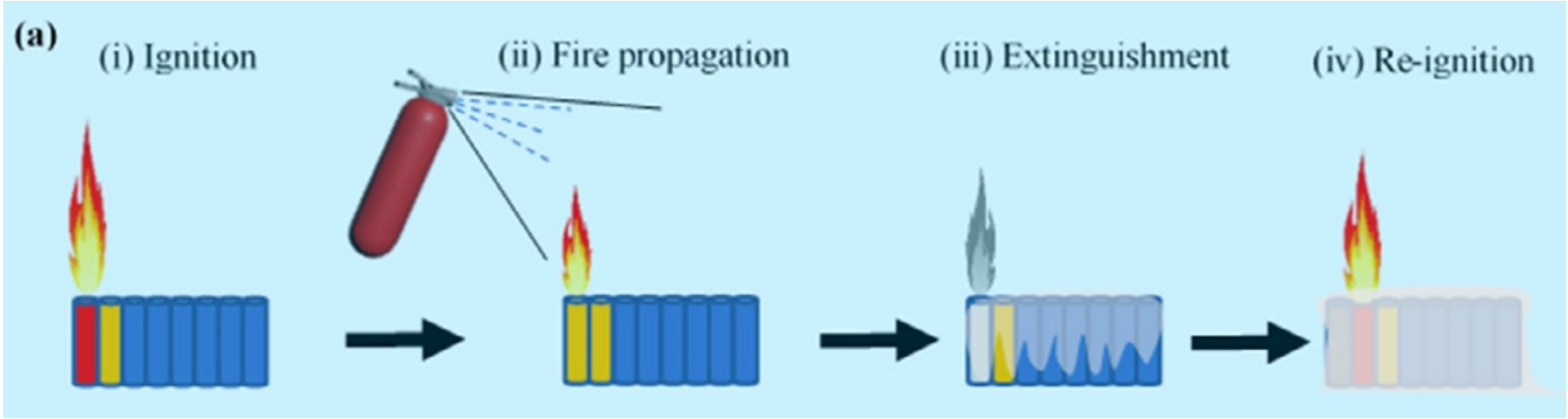




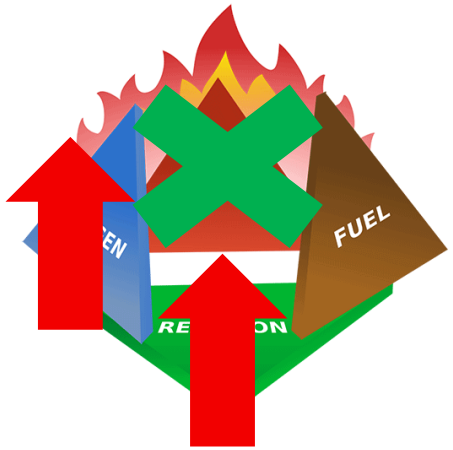
Technique comparison (ABC Powder)

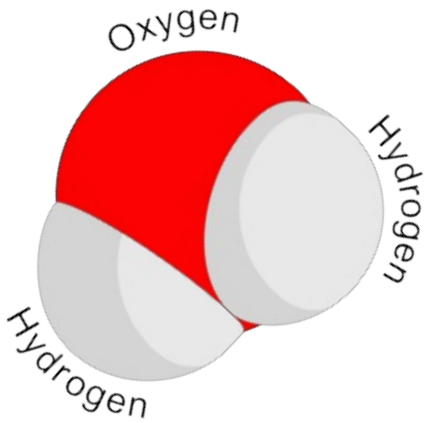


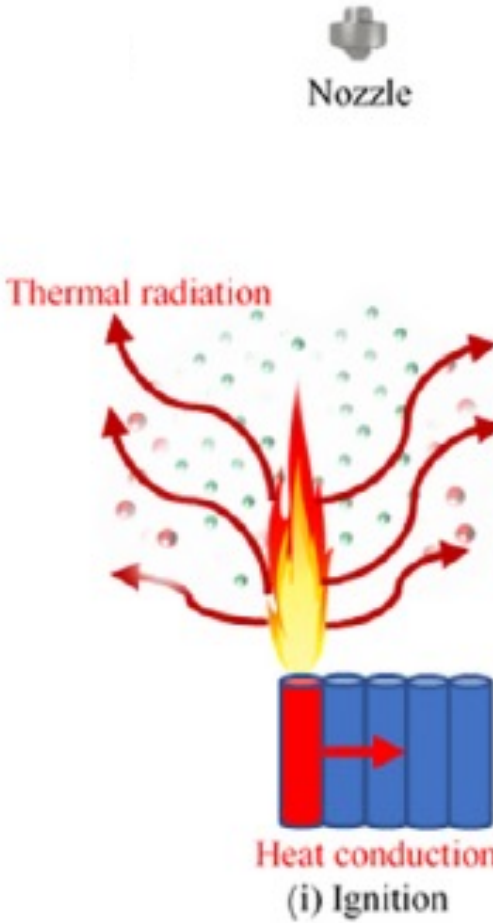
- ✗ Not suitable for self-sustaining oxygen source
- ✗ Surface extinguishment
- ✗ MAP decomposes at >200 ℃
  (release ammonia and phosphoric acid)
- ✗ Visibility hazard



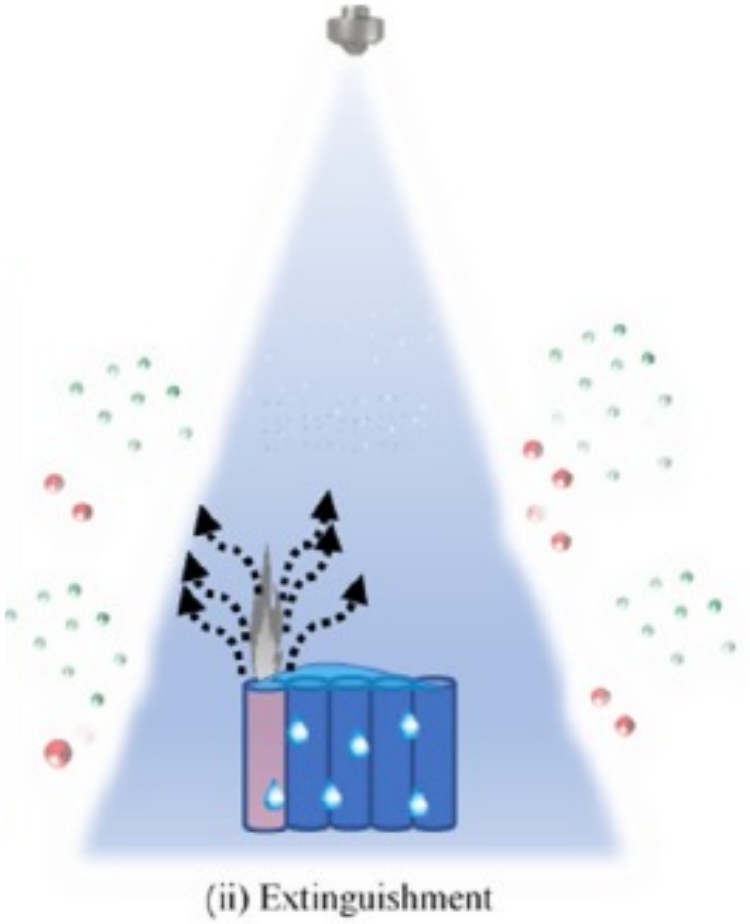
Technique comparison (Water mist)







❌ Not suitable for Class B, C and D
❌ Water vaporises (copious amount required)



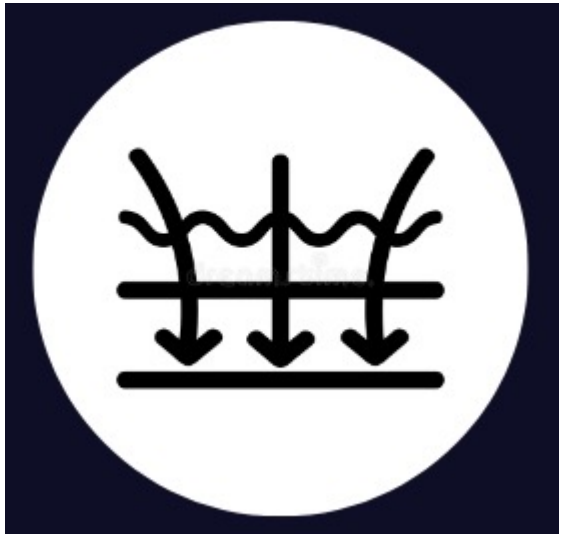
POWDER

FOAM

Source: HCT

TECHNOLOGY

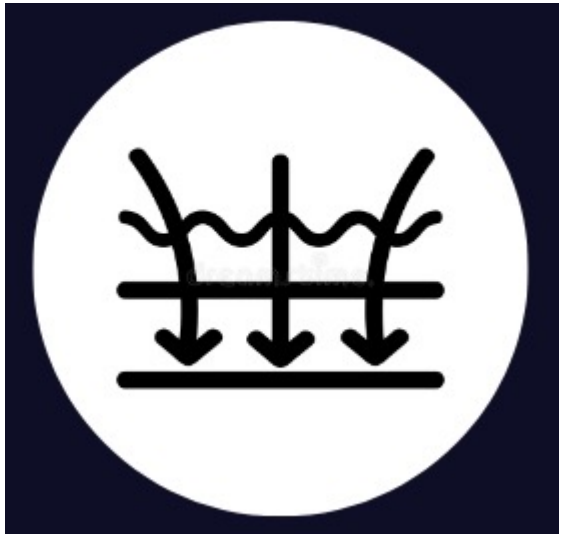
1. High heat absorption



- Absorbs heat rapidly upon contact with flames
- Natural products of high heat absorption capacity
- PyroGEL has high thermal effusivity and diffusivity

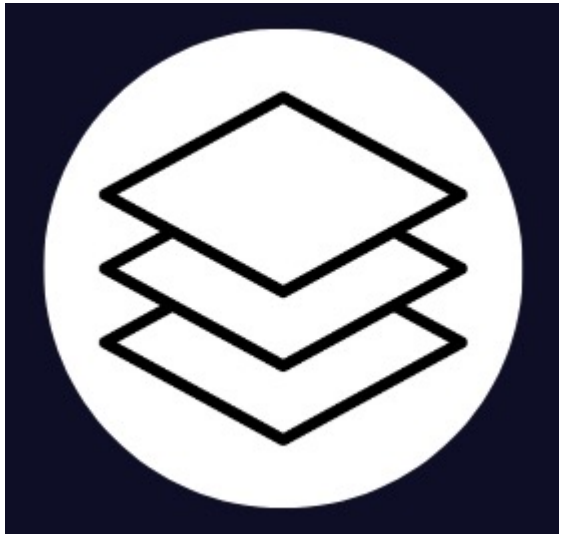
TECHNOLOGY

1. High heat absorption



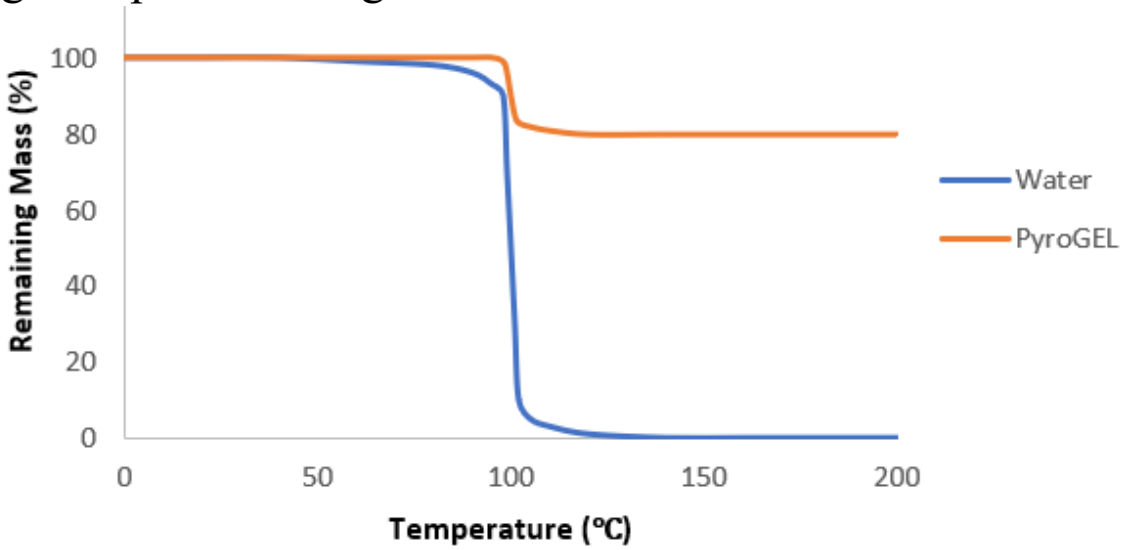
Δ		PyroGEL	Water	
+376%	Thermal conductivity ($W/m \cdot ℃$)	2.2860	0.6071	*How fast?*
+288%	Specific heat capacity ($J/kg \cdot ℃$)	12,081	4,200	*How much?*
	Thermal diffusivity (mm^2/s)	0.160	0.145	*How fast vs How much?*
+358%	Thermal effusivity ($W.\sqrt{s}/m^2 \cdot ℃$)	5,715	1,597	*How fast and How much?*

TECHNOLOGY



2. Cooling layer formation

- Refractory components
- Forms a protective layer that cools fire source across a very large temperature range
- Requires **5 times lesser (mass)** and **7 times lesser (volume)** of agent as compared with water



TECHNOLOGY

3. Reignition prevention

- Forms a viscous layer between fire and surroundings

  → Maintain fire suppression effect by cutting oxygen source

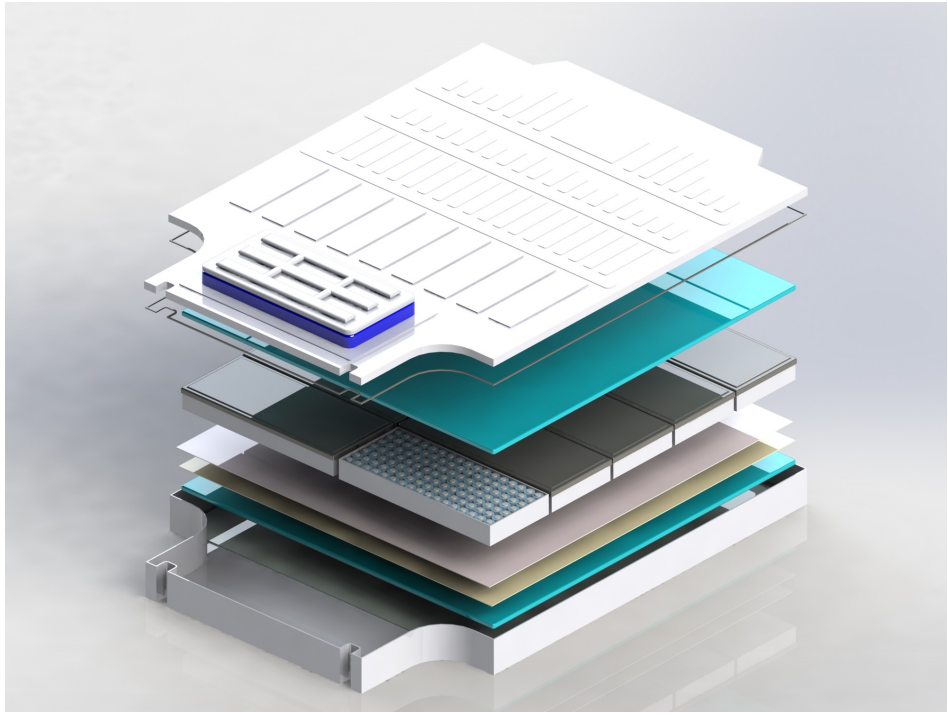
  → Minimize deflagration risks of burning battery

Features in action

PYROX®

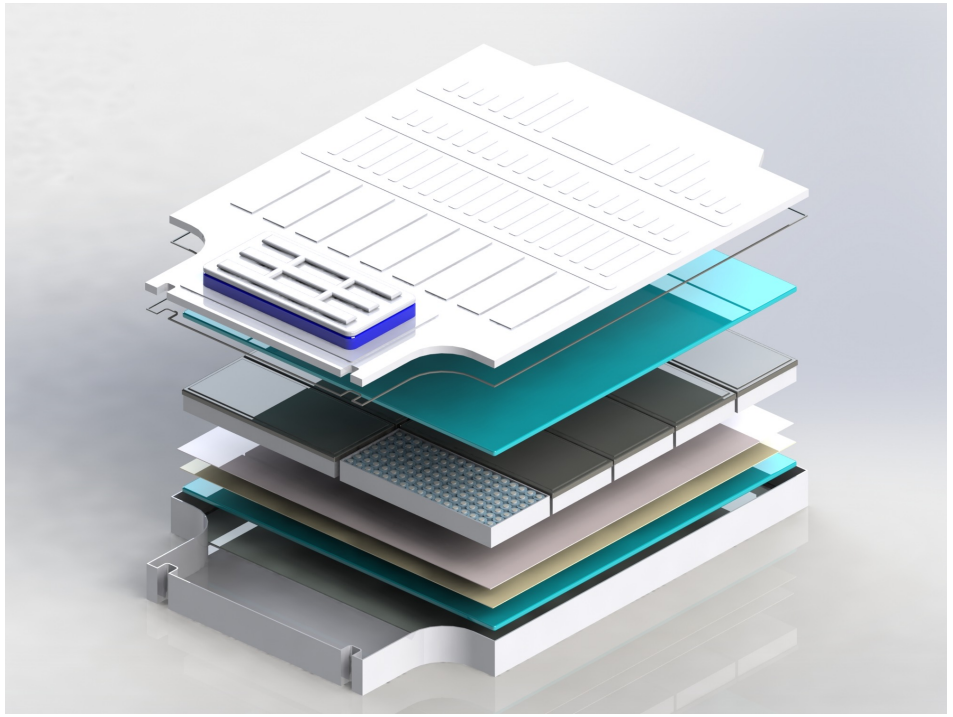
In-situ Fire Suppression Demo

Battery type: Lithium-ion battery (NMC pouch)
Battery amount: 4 units
Battery power: 100 Wh
Application: PyroGEL



BENEFITS

1. Non-toxic, natural and biodegradable products
2. High heat absorption
3. Low electrical conductivity (< 800 $\mu S/cm$)*
4. Can be retrofitted into existing systems
5. Non-pressurized agent without requiring control panels
6. Heat activated agent



*Drinking water: 200-800 $\mu S/cm$

ADDITIONAL TESTS

1. Electrical Conductivity Test

PYROX®

Electrical Conductivity Test

Battery type: Lithium-ion battery (NMC pouch)
Application: PyroGEL
Test: 3-h battery operation and immersion in PyroGEL

2. NTA8133 Test (Internal)

PYROX®

KIWA NTA8133 Test (Internal)

Battery type: Lithium-ion battery (NMC pouch)
Battery amount: 24 units
Battery power: 600 Wh
Application: 9 L PyroGEL extinguisher

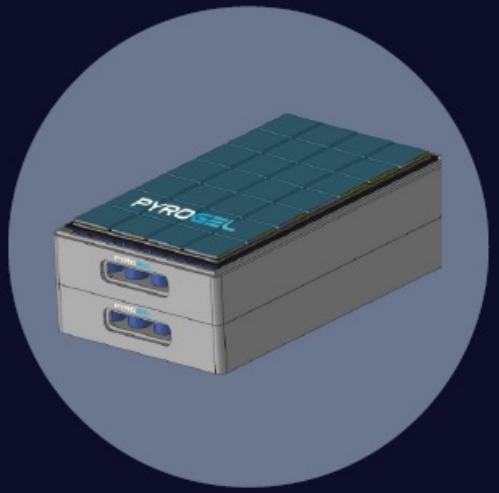
3. Comparative Test

PYROX®

Effective Battery Fire Suppression Demo

Battery type: Lithium-ion battery (NMC pouch)
Battery amount: 24 units
Battery power: 600 Wh
Application: 9 L PyroGEL extinguisher
Test protocol: KIWA NTA8133

PYROGEL APPLICATIONS

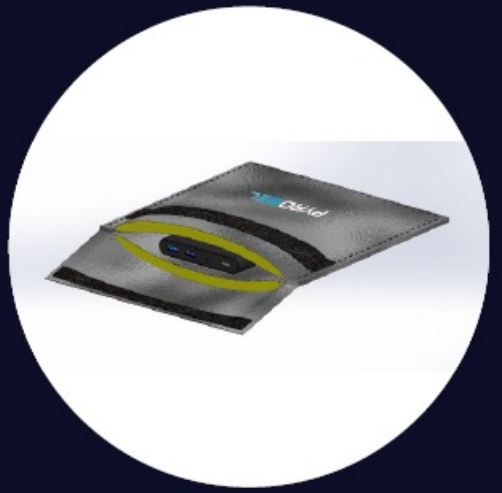


PyroBlanket

Manufacturing, Packing, Storage & Transportation.

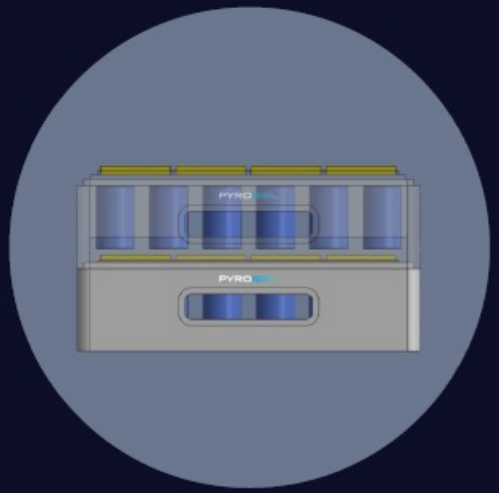
PPP
Pyro Protect Portable

2 wheelers batteries/portable batteries.



PPS
(Pyro Protect Sleeve)

Powerbank, cell phone & small lithium batteries

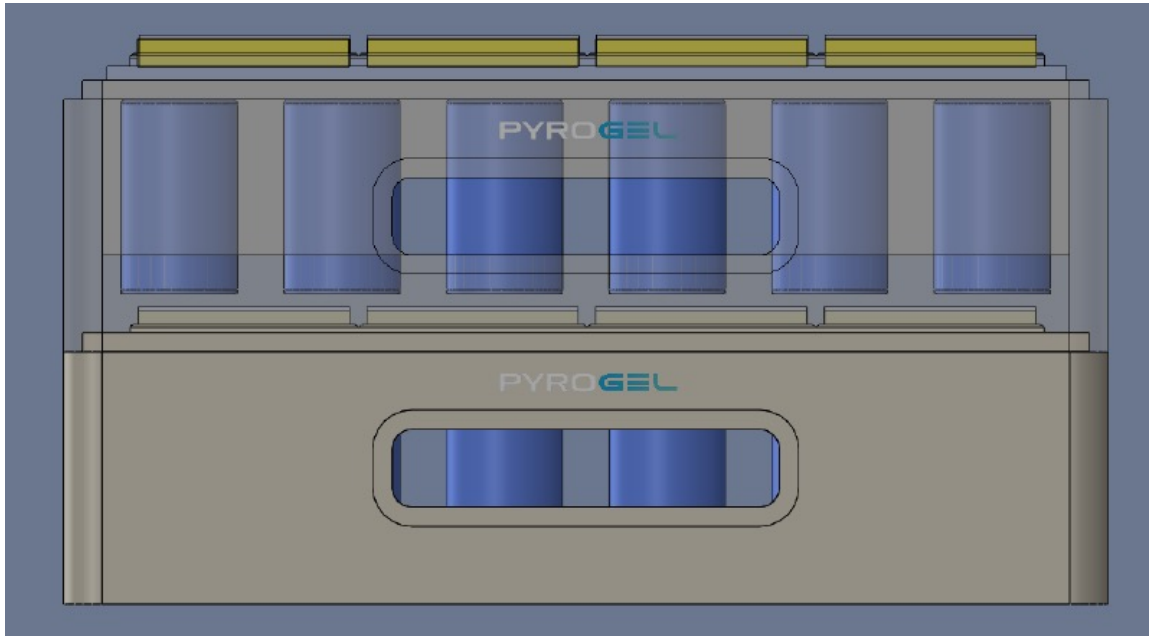


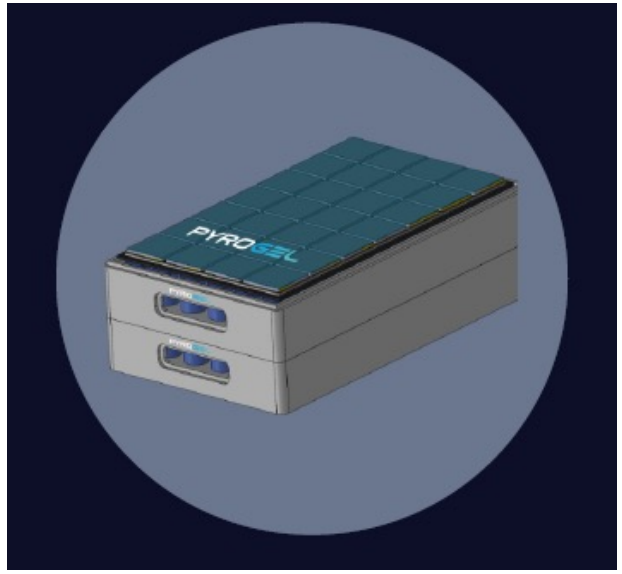
PYROX

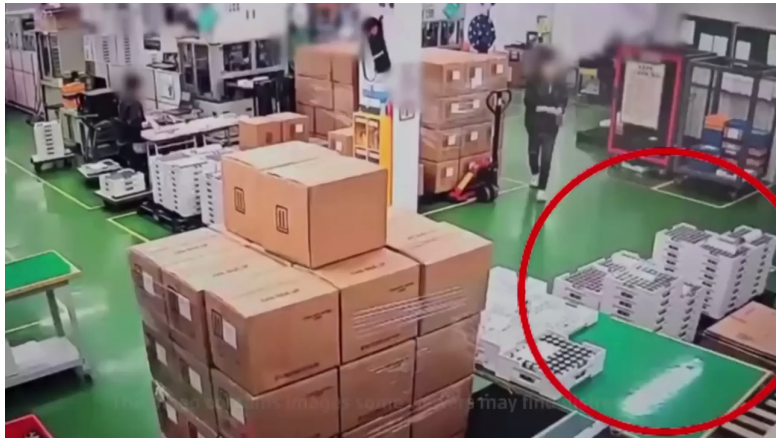
KEY APPLICATIONS

1. PYROBLANKET

Industry 1a. ***Manufacturing, storage and transportation of batteries***







Aricell, South Korea (June 2024)

Source: NY Post

Energy storage systems & Data centers

Singapore

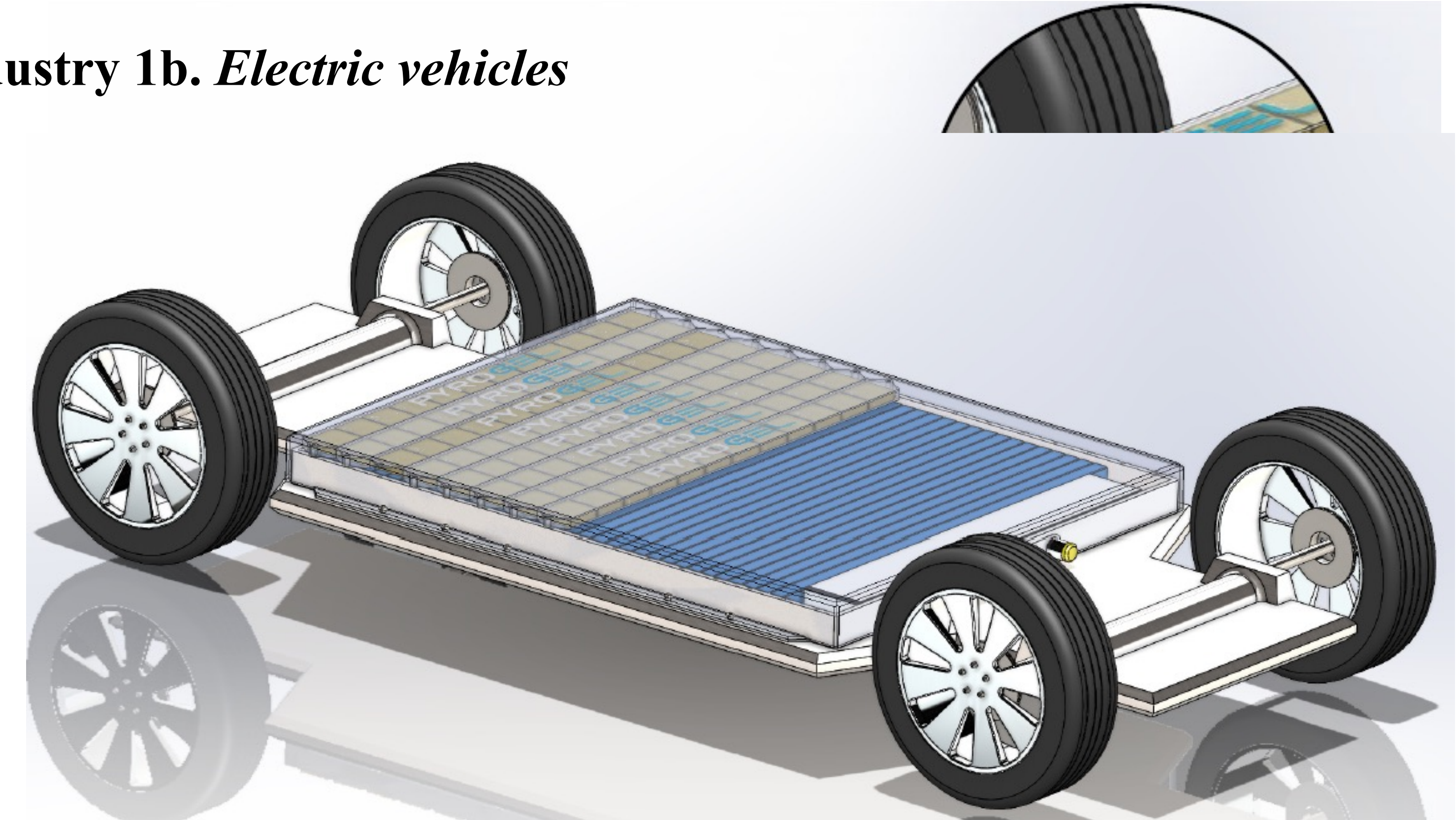
Fire at Loyang data centre, SCDF operations still ongoing after a day

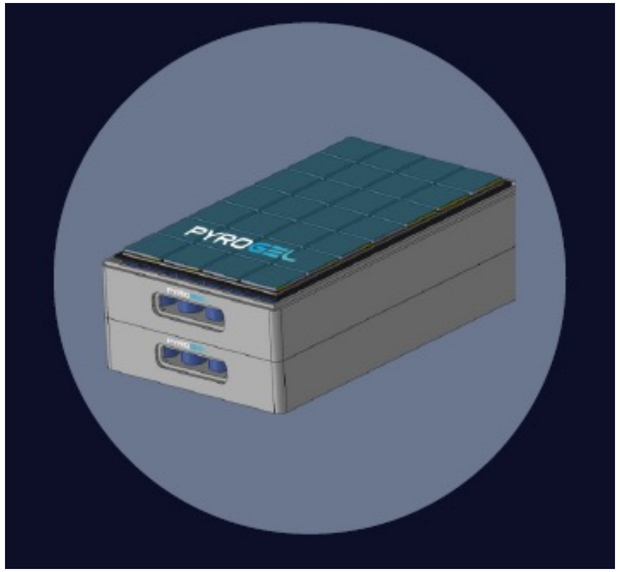
10 Sep 2024 11:47PM
(Updated: 11 Sep 2024 05:20PM)

KEY APPLICATIONS

1. PYROBLANKET

Industry 1b. *Electric vehicles*





Johor, Malaysia (Dec 2021)

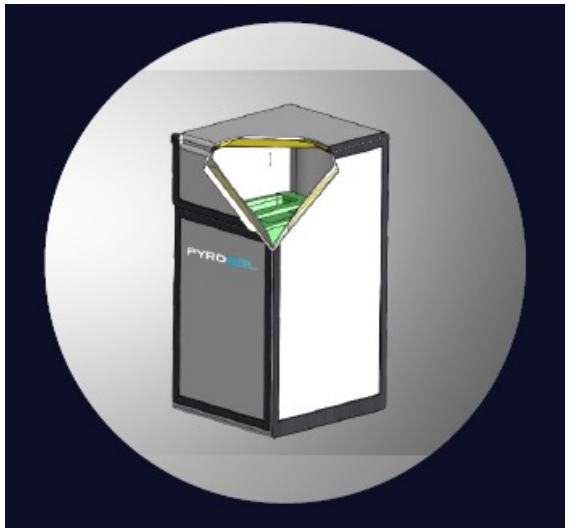
Source: The Star

PYROGEL

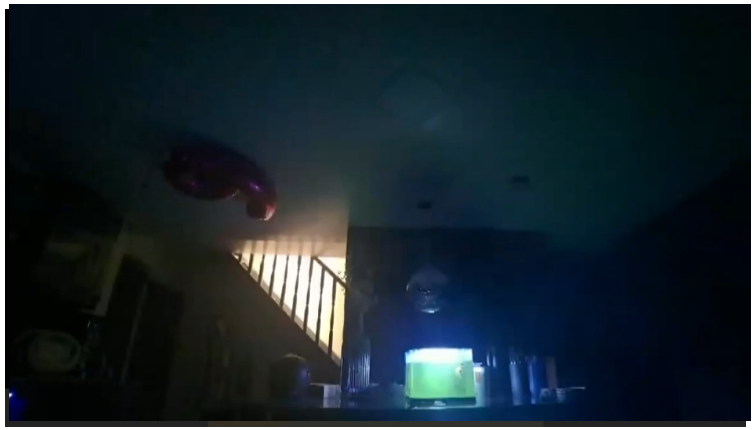
PYROX

KEY APPLICATIONS

2. PYROPROTECT PORTABLE



Industry 2. ***Two-wheelers' batteries***



West Yorkshire, UK (Jan 2023)
Source: BBC

Toronto Subway (Jan 2024)
Source: CBC

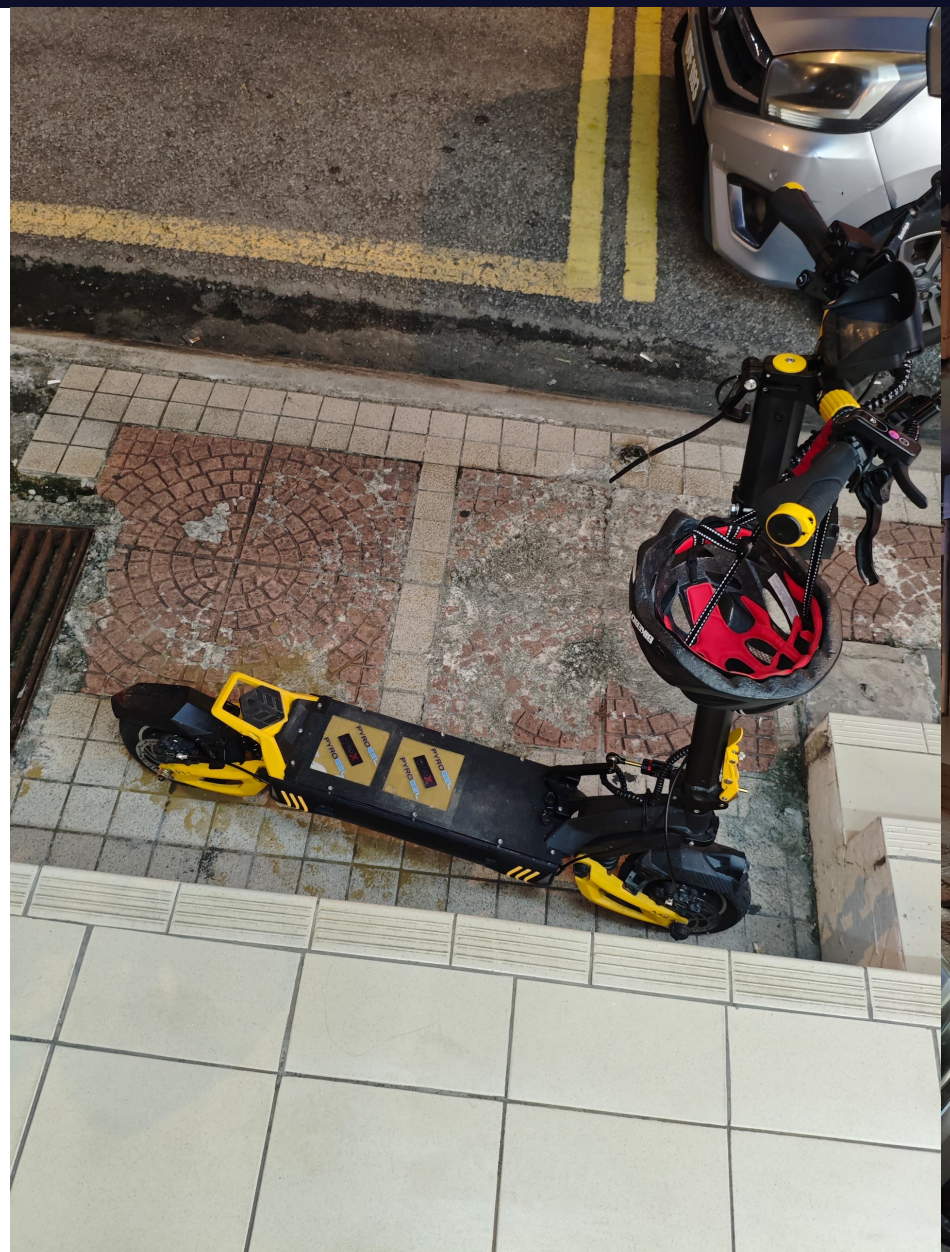
PYROX®

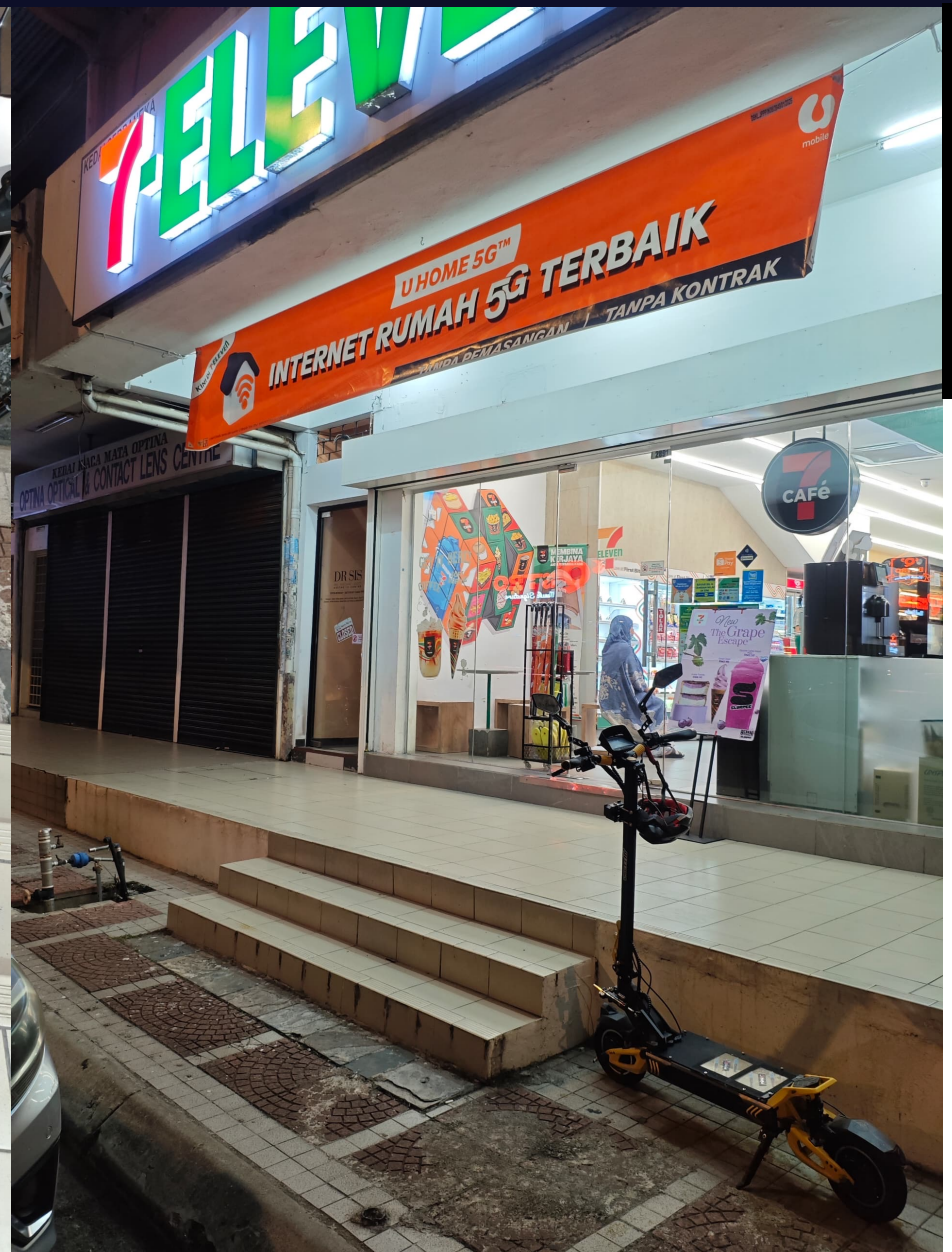
Simulation of EV Bike Fire Containment

Battery type: 18650 Lithium-ion battery
Battery amount: 16 cells
Battery power: 200 Wh
Application: PYROGEL

PYROGEL

PYROX

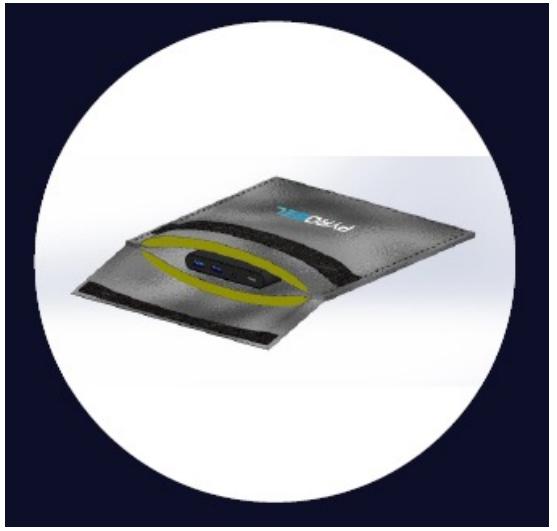




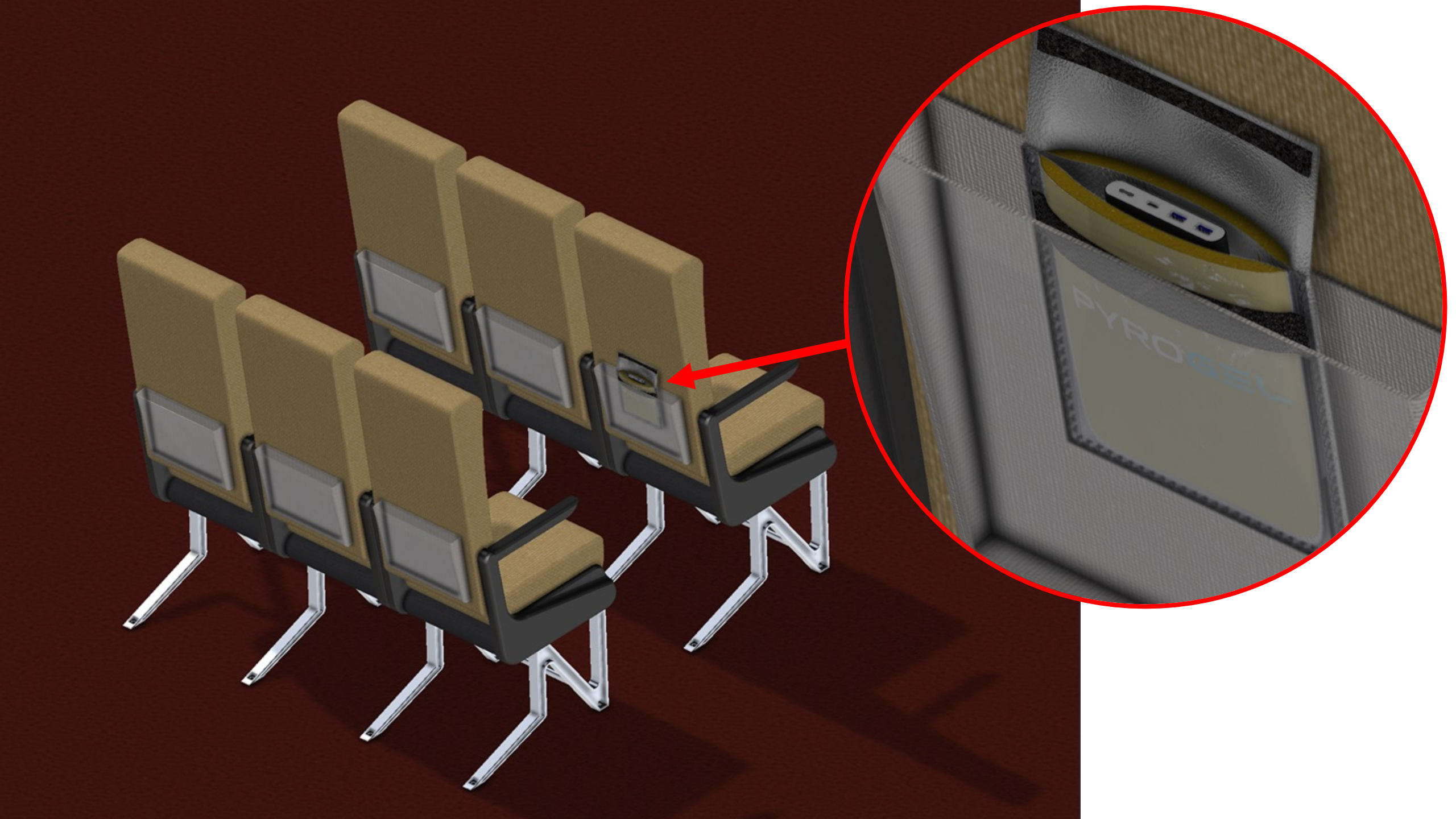
DR SCOOTER
infection in progress

KEY APPLICATIONS

3. PYROPROTECT SLEEVE



Industry 3. ***Aviation (Portable electronics)***

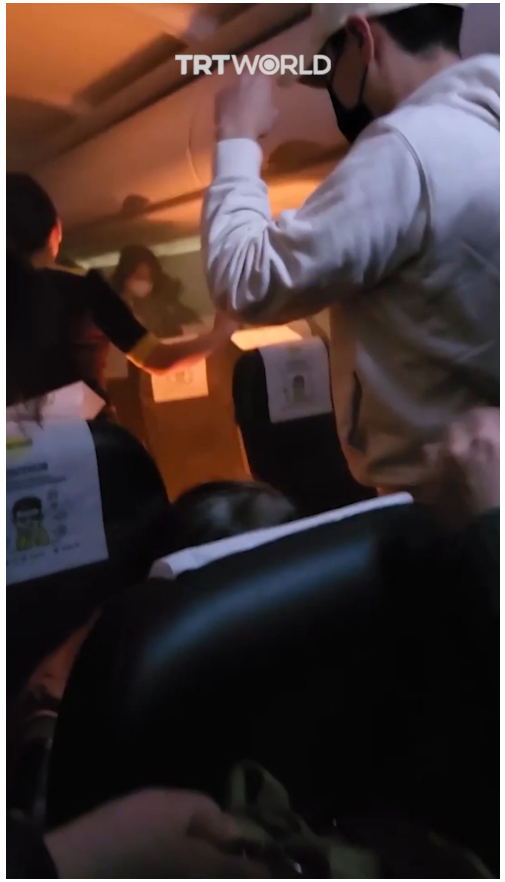

PYROGEL

PYROGEL

PYROX

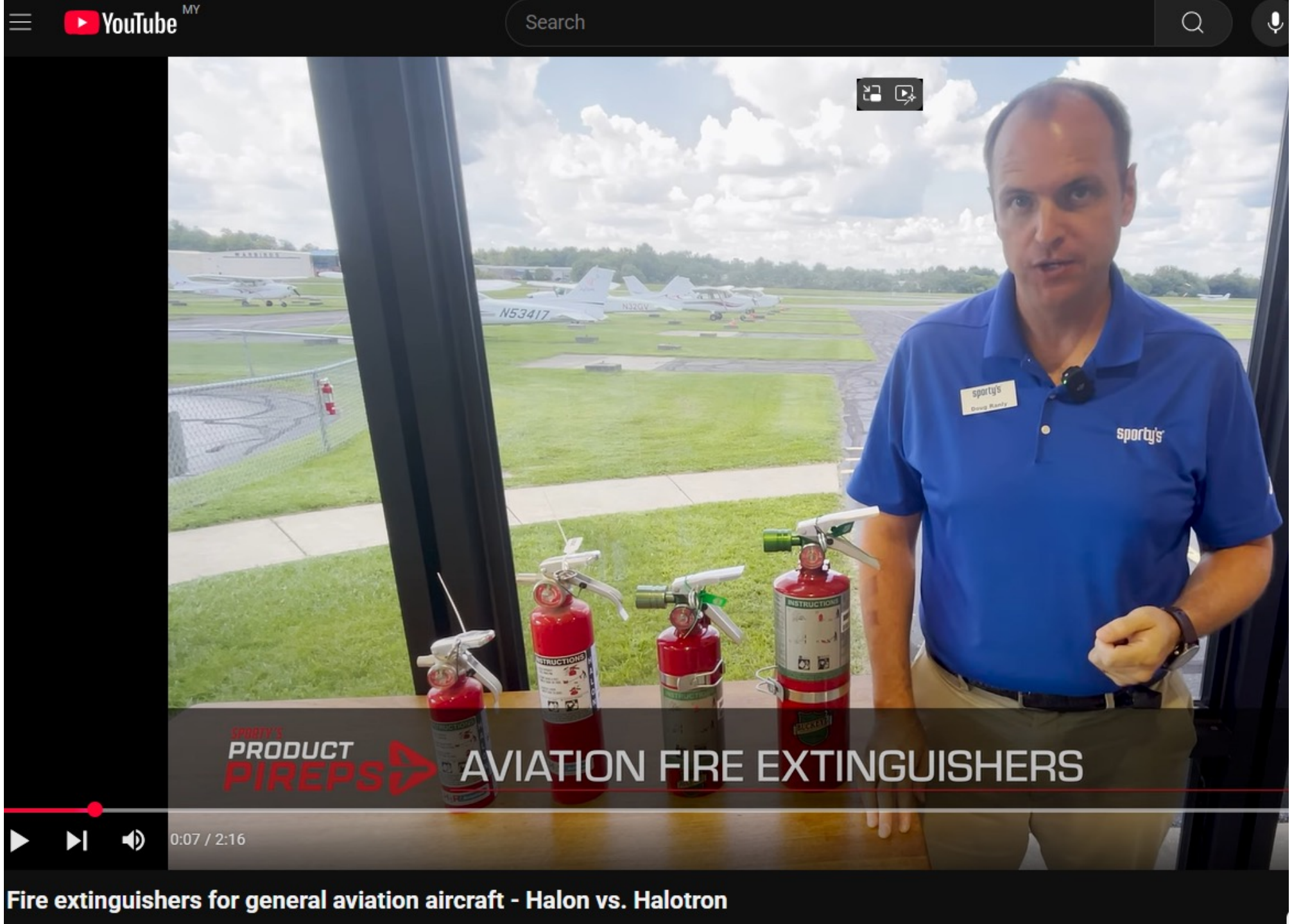
Subway

Aviation

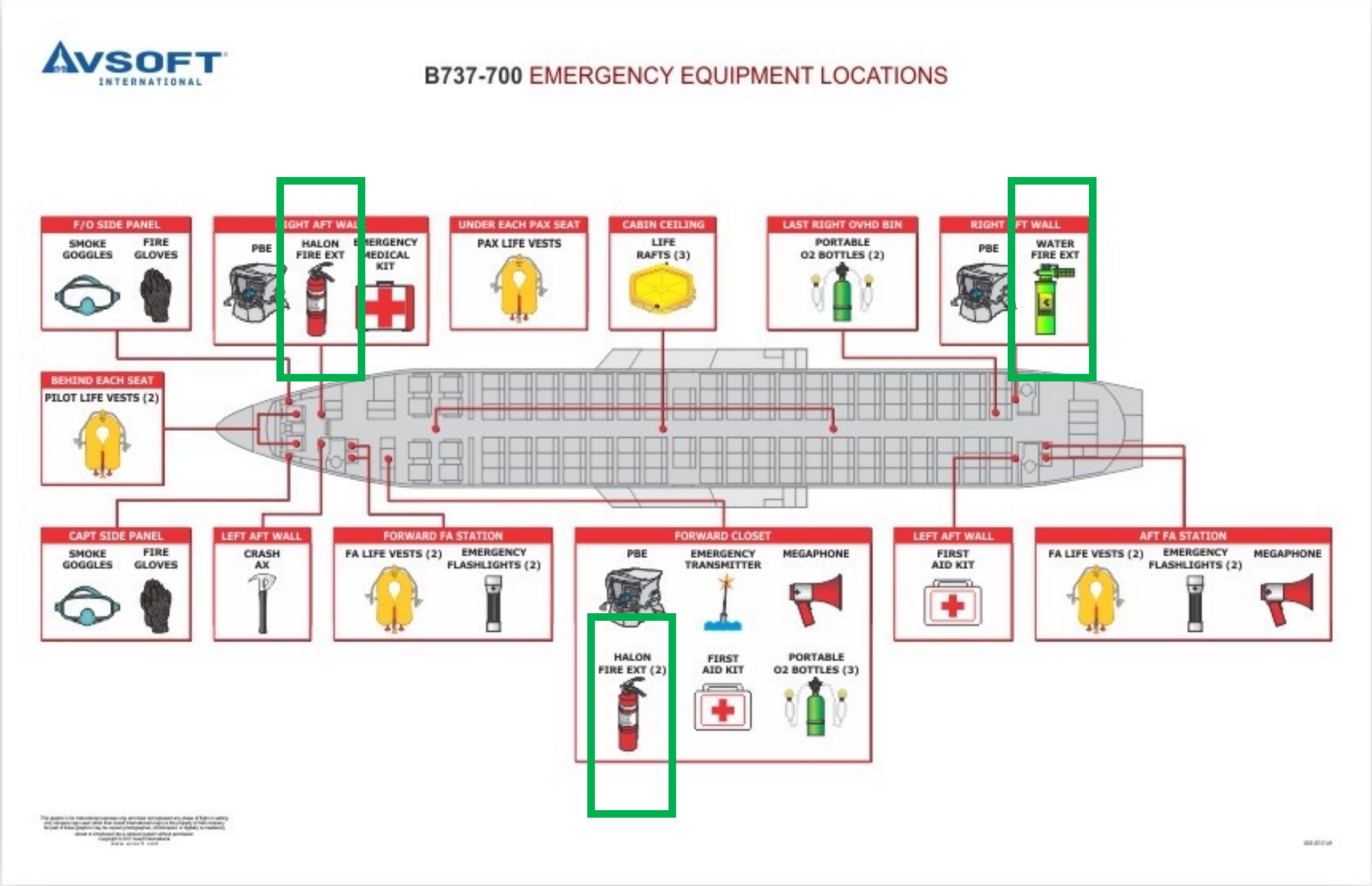


Anywhere & Everywhere….

Current practice?



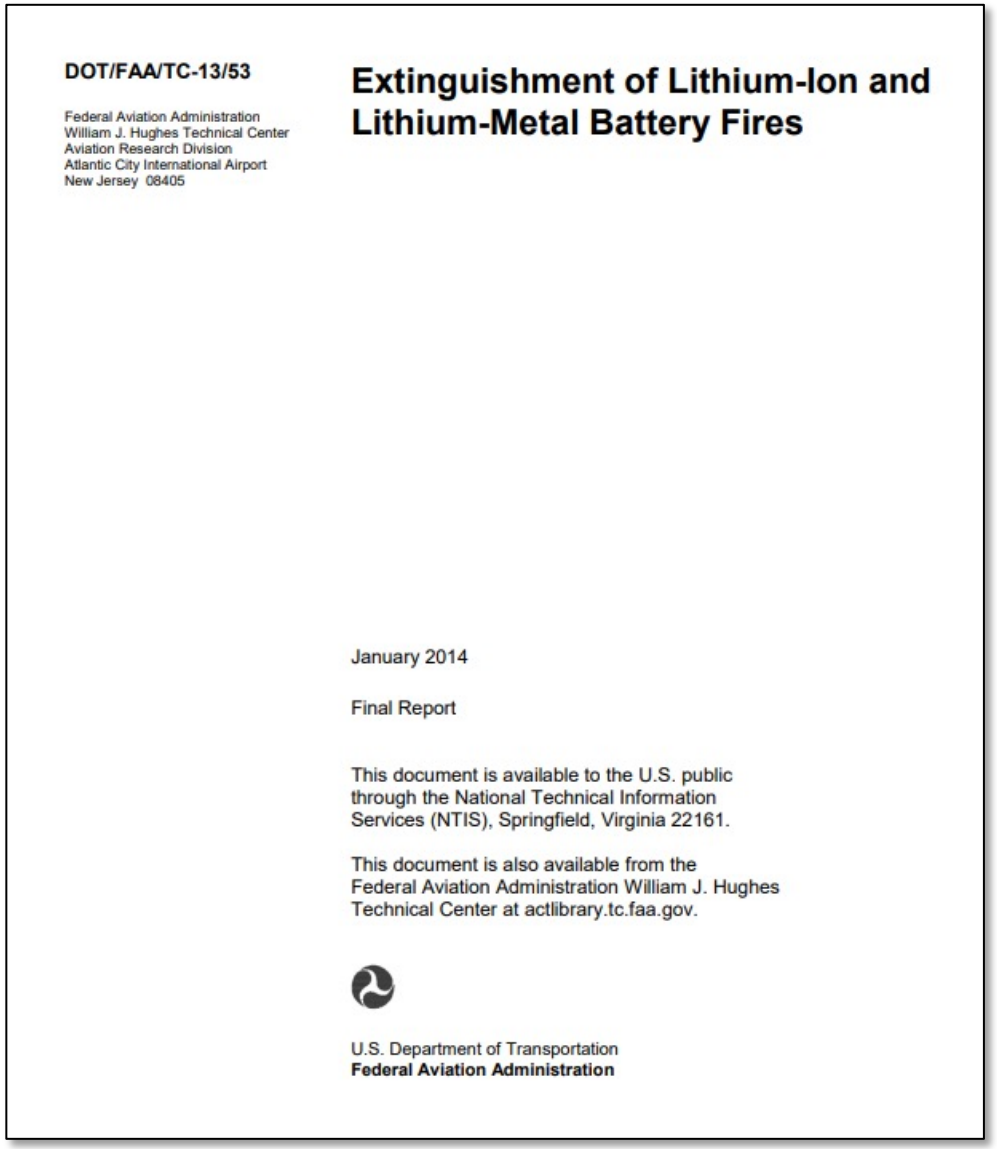
Fire extinguishers for general aviation aircraft - Halon vs. Halotron


AVSOFT INTERNATIONAL
B737-700 EMERGENCY EQUIPMENT LOCATIONS
F/O SIDE PANEL
SMOKE GOGGLES
FIRE GLOVES
IGHT AFT WAL
PBE
HALON FIRE EXT
ERGENCY MEDICAL KIT
UNDER EACH PAX SEAT
PAX LIFE VESTS
CABIN CEILING
LIFE RAFTS (3)
LAST RIGHT OVHD BIN
PORTABLE O2 BOTTLES (2)
RIGHT FT WALL
PBE
WATER FIRE EXT
BEHIND EACH SEAT
PILOT LIFE VESTS (2)
CAPT SIDE PANEL
SMOKE GOGGLES
FIRE GLOVES
LEFT AFT WALL
CRASH AX
FORWARD FA STATION
FA LIFE VESTS (2)
EMERGENCY FLASHLIGHTS (2)
FORWARD CLOSET
PBE
EMERGENCY TRANSMITTER
MEGAPHONE
HALON FIRE EXT (2)
FIRST AID KIT
PORTABLE O2 BOTTLES (3)
LEFT AFT WALL
FIRST AID KIT
AFT FA STATION
FA LIFE VESTS (2)
EMERGENCY FLASHLIGHTS (2)
MEGAPHONE

Federal Aviation Administration

US Department of Transportation

→ Technical report on the effectiveness of various fire suppression agents on lithium-ion and lithium metal battery fires



DOT/FAA/TC-13/53

Federal Aviation Administration
William J. Hughes Technical Center
Aviation Research Division
Atlantic City International Airport
New Jersey 08405

Extinguishment of Lithium-Ion and Lithium-Metal Battery Fires

January 2014

Final Report

This document is available to the U.S. public through the National Technical Information Services (NTIS), Springfield, Virginia 22161.

This document is also available from the Federal Aviation Administration William J. Hughes Technical Center at actlibrary.tc.faa.gov.

U.S. Department of Transportation
Federal Aviation Administration

https://www.fire.tc.faa.gov/pdf/TC-13-53.pdf

Table 2. Lithium and Lithium-Ion Battery Test Results

Test Number	Agent	Cell Chemistry	All of the Cells Propagated	None of the Cells Propagated
1-4	No agent	Lithium-Ion		
5	Water	Lithium-Ion		
6	Water	Lithium-Ion		
7	Water	Lithium-Ion		
8	Aqueous A-B-D	Lithium-Ion		
9	Aqueous A-B-D	Lithium-Ion		
10	Aqueous A-B-D	Lithium-Ion		
11	AF-21	Lithium-Ion		
12	AF-21	Lithium-Ion		
13	AF-21	Lithium-Ion		
14	AF-31	Lithium-Ion		
15	AF-31	Lithium-Ion		
16	Novec 1230	Lithium-Ion		
17	Novec 1230	Lithium-Ion		
18	Novec 1230	Lithium-Ion		
19	Halon 1211	Lithium-Ion		
20	Halon 1211	Lithium-Ion		
21	FM-200	Lithium-Ion		
22	FM-200	Lithium-Ion		
23	Halotron I	Lithium-Ion		
24	Halotron I	Lithium-Ion		
25	FE-36	Lithium-Ion		
26	Purple-K	Lithium-Ion		
27	Purple-K	Lithium-Ion		
28	CO2	Lithium-Ion		
29	CO2	Lithium-Ion		

- Failed to suppress fire
- Thermal runaway

https://www.fire.tc.faa.gov/pdf/TC-13-53.pdf

Euronews + Follow 46.9K Followers

Some airlines are banning power banks on flights. Here's what travellers need to know

Story by Rebecca Ann Hughes • 1w • 3 min read Summarise

The aviation industry's heightened caution around power banks comes after several incidents of fires caused by malfunctioning batteries.
© Rebecca Aldama

Travel Restrictions on Power Banks

airasia Points: 46

Dear Andrew Kay Lup ,

AirAsia is dedicated to the safety and comfort of all passengers. To maintain the highest safety standards and reduce risks related to lithium battery incidents, we have implemented strict regulations for the carriage and use of power banks on all AirAsia flights. We kindly request all guests to familiarize themselves with and follow these new regulations.

Effective 1st April 2025, using or charging of power banks irrespective of the power bank's capacity or certification is strictly prohibited onboard all AirAsia flights.

This restriction applies to all flight phases, including boarding, in-flight, and disembarkation.

- Power Banks are prohibited from being stored in the overhead compartment storage and must be carried on your person or in the seat pocket in front of you.
- These items must be individually packed—either sealed in a plastic or insulated pouch or kept in their original retail packaging to prevent short circuits.

Clean agent??

Long flight distance??

Battery re-ignition??

Two tanks per plane?

PREVENTION AS THE BEST OFFENSE

n-situ fire suppression

hock absorption

as absorption

✓ Heat absorption

✓ Re-ignition prevention

PYROGEL

PYROX

IFCEM 2024, 22-24 Oct (PyroGEL launch)

E-Mobility Asia 2024, 12-14 Nov (PyroGEL showcase)

18 PATENTS FILED

- Fire Extinguishing System for Electric Vehicles (MY, PH, ID, SG, World)
- Improved Fire Extinguishing System for Electric Vehicles (MY, World)
- An Apparatus for Fire Prevention and Protection (MY, World)
- Fire Extinguishing Composition Suitable for Multiple Classes of Fire (MY, World)
- Gel Composition for Extinguishing Fire (MY, World)
- A Device for Automated Fire Extinguishment (MY, World)
- Gel-Filled Packaging System for Fire Protection of Batteries and Electric Components (MY, World)
- Gel Based Fire Extinguishing Pack for Electric Motorcycles (MY, World)

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IPOS INTELLECTUAL PROPERTY OFFICE OF SINGAPORE

INTELLECTUAL PROPERTY OFFICE OF THE PHILIPPINES

DGIP DIRECTORATE GENERAL OF INTELLECTUAL PROPERTY MINISTRY OF LAW AND HUMAN RIGHTS REPUBLIC OF INDONESIA

THANK YOU!

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