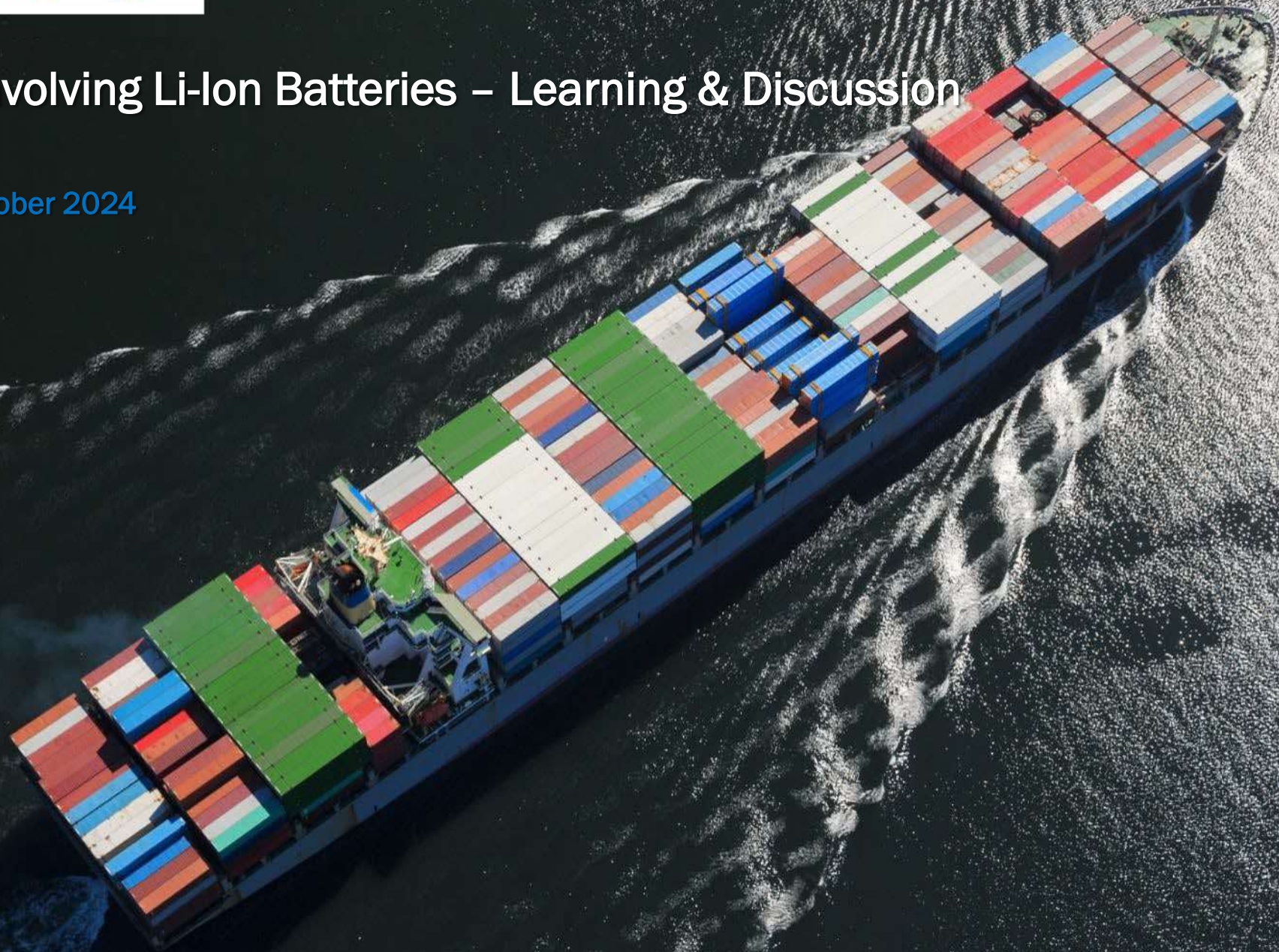


Maritime Fires involving Li-Ion Batteries – Learning & Discussion

ARCSOPT Meeting

Perth, Australia – 23 October 2024





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1. Why is this topic of interest to Seafarers and Port Officials



Brookes
Bell

Lithium-Ion Batteries are part of our everyday lives, but...



Extensively-Assembled Battery Energy Storage Systems Remain a Huge Danger in the Industry

engineeringnews.co.za • 4 min read



Battery and charging safety

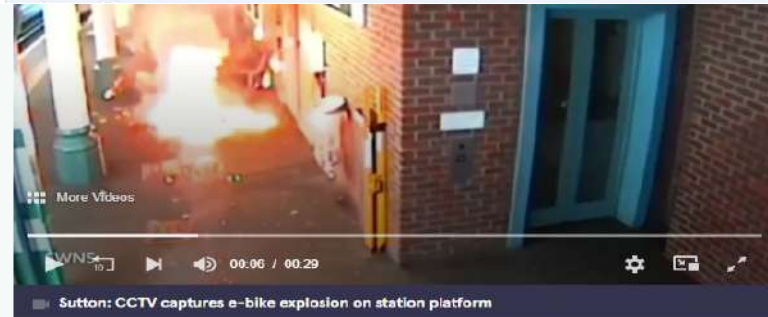
fire.nsw.gov.au • 2 min read

Over 50 Rivian EVs Damaged In Factory Parking Lot Fire. Here's What Happened (Updated)

The damaged R1S and R1T vehicles were reportedly waiting to be shipped to customers.



26.08.24



Sutton: CCTV captures e-bike explosion on station platform

- NEWS
- POLITICS
- FOOTBALL
- CELEBS
- TV
- SHOPPING
- ROYALS

E-bike explodes in 'ferocious' fire on train station platform as owner watches on

21.03.24

Fire crews raced to the railway station after the e-bike exploded into flames on the platform as its owner watched on. Video footage captured the moment that the fire broke out

By Rom Preston-Ellis, Assistant News Editor & Jacob Freedland

14:22, 8 Apr 2024



News > Scottish News

BATTERY BLAZE TERROR Massive fire at Kilwinning battery recycling plant as explosions heard for miles and locals told to evacuate

Locals were ordered to leave their homes as acrid fumes engulfed the surrounding neighbourhood

Lisa Hodge

Published: 1:00, 9 Apr 2024 | Updated: 11:22, 9 Apr 2024

8.04.24

Luton Airport fire: Flights resume after blaze rips through car park

4 days ago



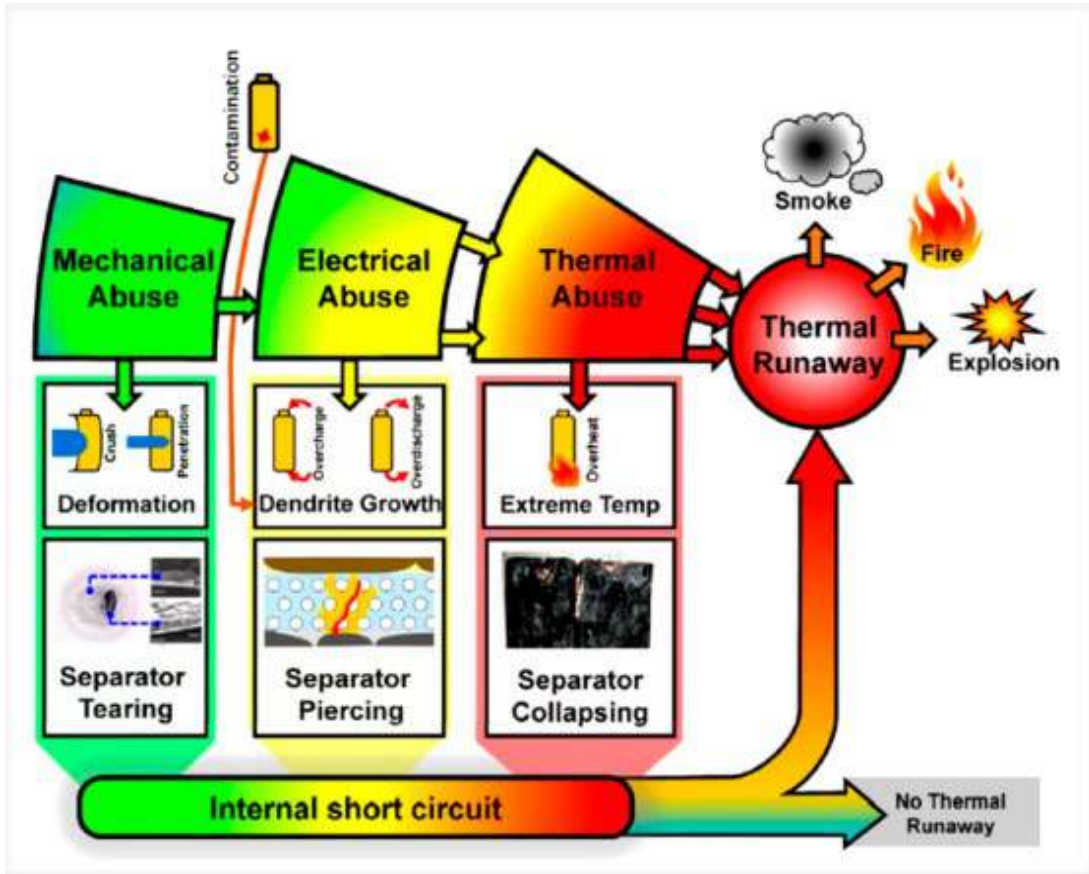
11.10.23



Watch: The roof of the car park at Luton airport engulfed in flames

2. Gases produced during thermal runaway

Why do Li-ion Batteries Pose a Fire Risk?

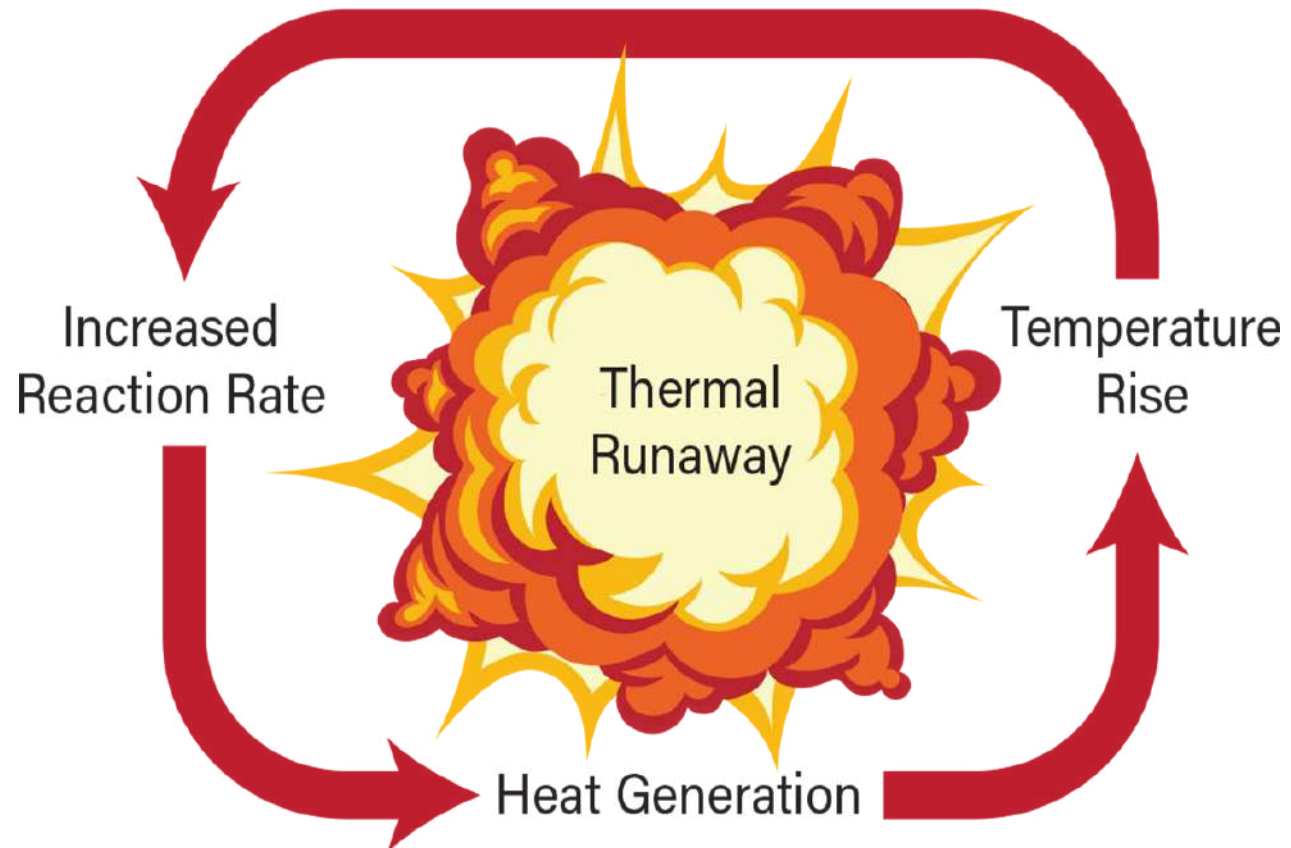


Reference: *Appl. Sci.* 2021, 11(3), 1247

Main reasons for the risk:

1. Improperly manufactured, poor quality materials
2. Battery management software faults
3. Battery Abuse:
 - Mechanical damage dropped or in the case of vehicles, involved in a collision or accident
 - Over-charging/ over-discharging
 - Exposure to extreme temperatures/ high local temperature
4. Short circuit- external and internal short circuits
5. End of Life

Thermal Runaway

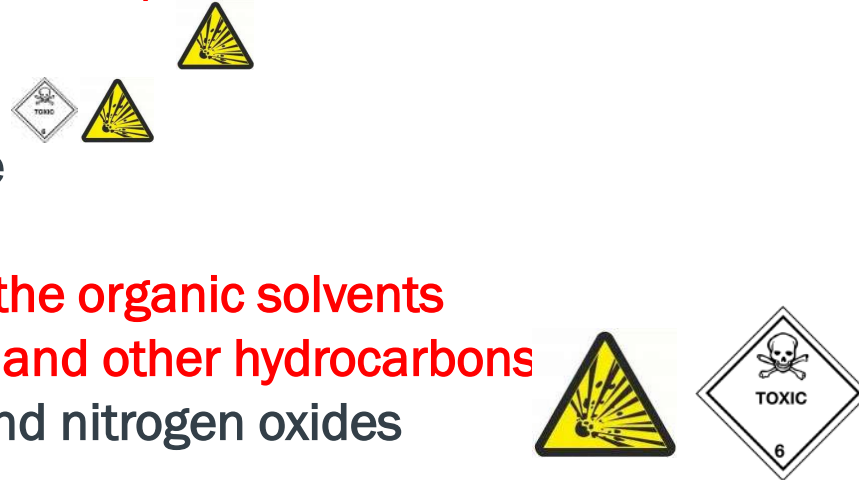


- **Self-sustaining reaction-** can be very difficult to stop once it has started.
- **Rapid-** the battery cell temperature can rise incredibly fast (milliseconds). The energy stored in that battery is released very suddenly.
- **Hot-** creates extremely high temperatures (upwards of 1,000 °C).
- **Fire-** this can be so hot that it is almost impossible to extinguish.
- **Vapours-** toxic and hazardous gases can be released from the battery, these can be explosive.

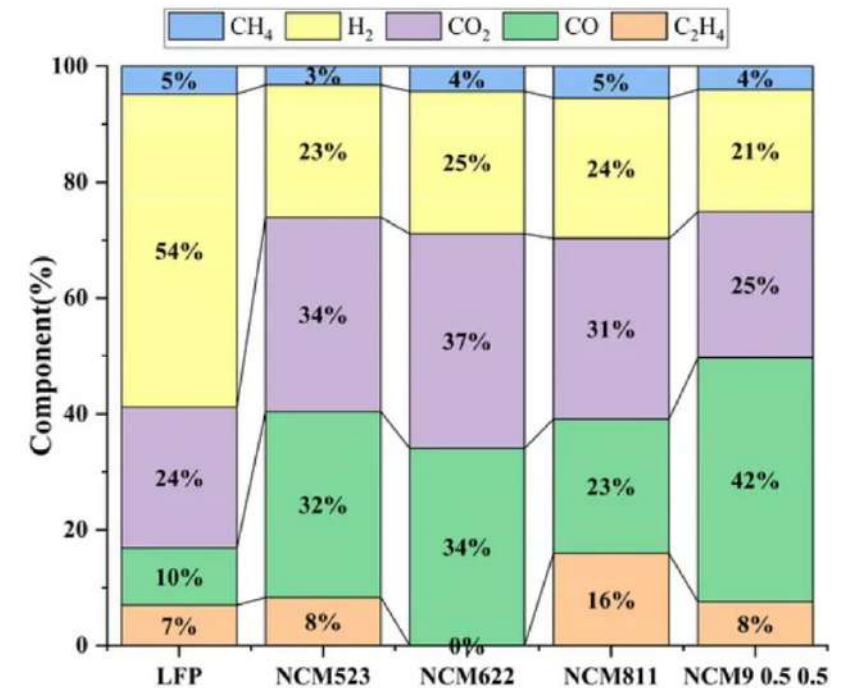
Thermal Runaway – Be Warned – IT IS NOT SMOKE!

In thermal runaway and prior to ignition, lithium-ion Batteries vent a white vapour which consists of:

- hydrogen (ca. 25 – 50%)
- carbon monoxide
- hydrogen fluoride
- hydrogen chloride
- hydrogen cyanide
- small droplets of the organic solvents
- ethane, methane and other hydrocarbons
- sulphur dioxide and nitrogen oxides
- carbon dioxide



i.e. a VAPOUR CLOUD



The cloud can produce upto 6,000 litres of Vapour from a 1kWh battery (or 600,000 litres from 100kWh).

NOTE: Current 2022 Car Models have between 21kWh (e.g. Fiat 500e) to 108kWh (e.g. Mercedes EQS 450+)

[Useable battery capacity of full electric vehicles cheatsheet - EV Database \(ev-database.org\)](https://ev-database.org/)

3. Examples of Thermal Runaway

First example of Thermal Runaway

-

In the Lounge at Home (with dog and Daughter)



Seven seconds from Battery Failure until Room is filled with Toxic Vapours



Thermal Runaway in action... Note the different gas layers.

27secs



4. Examples of Vapour Cloud Explosion

Hybrid Jeep Explosion (11/04/2023)



5. Lessons Learned from a Recent Case

ADDITIONAL CONSIDERATIONS FOR ALL

Potential additional challenges to consider when Electric Vehicles are involved



2023 - PCTC Fire

Explosion within Upper Deck
Deck Set up 2.5m over 100m

Likely Vapour Cloud Explosion

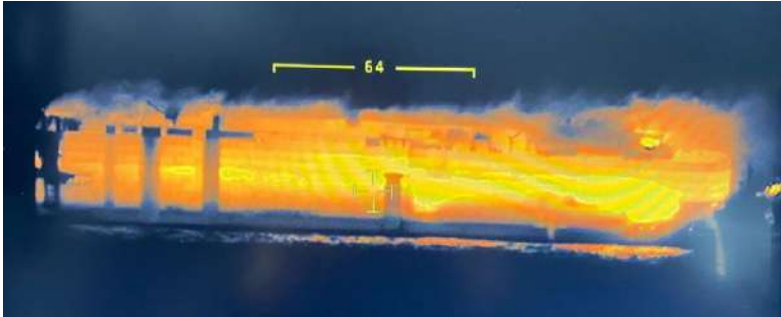
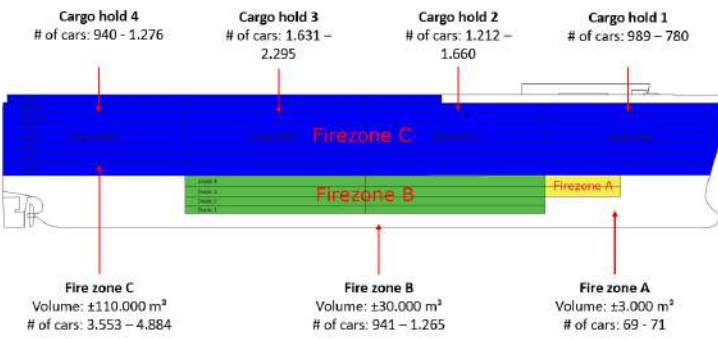
Access to Lifeboats restricted

Access to Lower Decks restricted

Fire Main Compromised



Potential additional challenges to consider when Electric Vehicles are involved



Potential additional challenges to consider when Electric Vehicles are involved

Foam Suppression System deployed. Could this have resulted in gases passing through foam without igniting such that a gas cloud form in the upper deck in significant quantities. Some estimates for damage of this nature circa 1million litres of gas would have been required to cause this damage. Hydrogen has an overpressure of 0.1bar on ignition. Food for thought again...



2023 - PCTC Fire

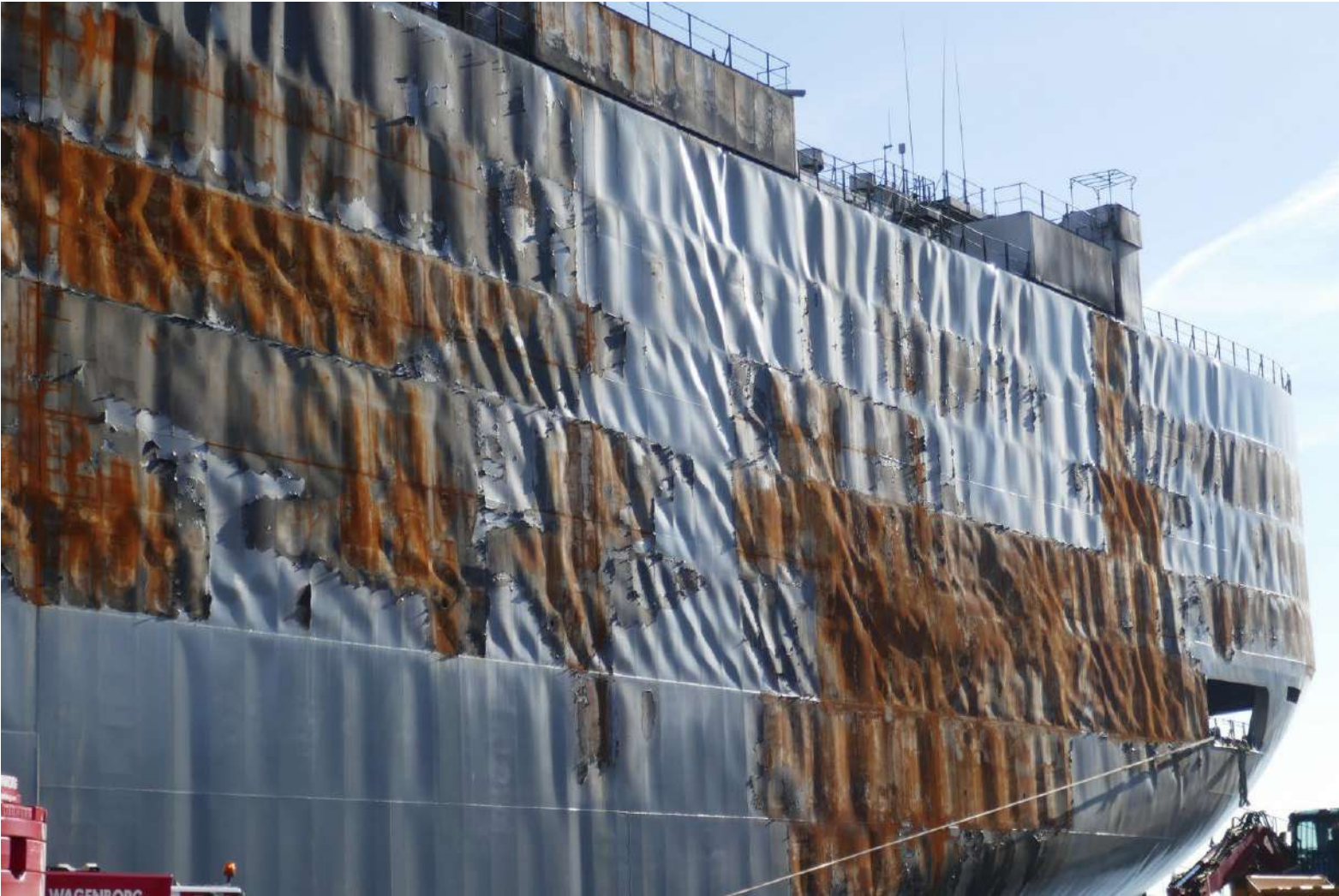
Evidence of an explosion within the Upper Deck

Deck Set up 2.5m over 100m of length

Full canopy deck displaced preventing access to Lifeboats

Fire main displaced removing ability to boundary cool or add foam.

Potential additional challenges to consider when Electric Vehicles are involved



Movement of vehicles, Toxicity of dust and other matter

Structural damage to internal and external items resulting in displacement and failure of decks.



Potential additional challenges to consider when Electric Vehicles are involved



Minion Land – Aluminium melting point is 660°C

At what temperature does it need to reach to flow over many metres?

Some of these stalagmites were 2m high and 0.5m round.

Molten Aluminium also flows

Stalagmites from vehicles found on decks below

Transfer of heat downwards

Possible blocking of scuppers



Potential additional challenges regarding fires involving Electric Vehicles on Ships



On the recent case, the Fire Water was tested and found to have:

*Various Heavy Metals
Various Toxins
Ph level of 4.7*

Food for thought and post incident considerations:

If an EV is only partially burned, is there any residual risk for further fire or toxic gases being generated?

What Toxins are likely to be on every surface within the space?

What is the breathable atmosphere likely to contain?



Potential additional challenges regarding fires involving Electric Vehicles on Ships



FOOD FOR THOUGHT

Full electric vehicle

Battery involved in fire but based on evidence has not gone into thermal runaway with fire.

Battery was dragged along deck but didn't have a problem.

Reported that a battery subject to high temperatures will start to dry out and can vent gases without Thermal Runaway...

If correct, how much gas?

Thereafter, if suppressant system is working, and no flames present, what happens to the gases being generated...

Again, Tests are suggesting upto 6,000ltrs per 1Kwh Battery of which 30-50% is hydrogen...

Potential additional challenges regarding fires involving Electric Vehicles on Ships



FOOD FOR THOUGHT:

Fire blankets for protection.

Challenging to actually install in first place.

Can you get them to deck level?

This example shows four fire-fighters trying to install prior to moving adjacent unit and couldn't fit.

Potential additional challenges regarding fires involving Electric Vehicles on Ships



FOOD FOR THOUGHT

Full electric vehicle submerged in fire water.

Battery fire occurred while bringing up internal ramp (in reverse as advised).

Salvage team on scene and handled immediately.

Landed in skip following fire-fighting on board.

Fire/venting of gases resumed after 10 mins and container was flooded to extinguish. Left for 48 hours, but recommendation was minimum 6 days.

One manufacturer raised concerns about using seawater for fire-fighting....

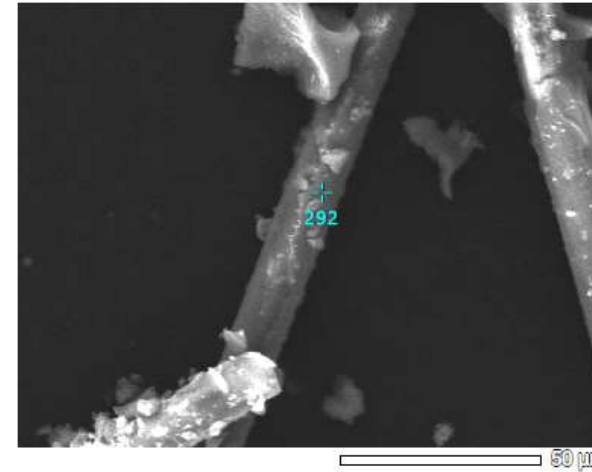


Potential additional challenges regarding fires involving Electric Vehicles on Ships

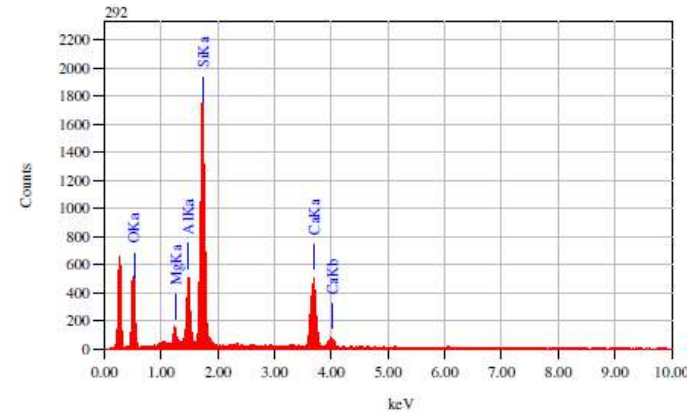
FIRE WATER ANALYSIS

TEST	RESULT	UNIT
Appearance	Brown water	-
Chemical oxygen demand	44100	mg/l
Acidity (pH) at 20°C	4,79	-
Total dissolved solids	21	mg/l
Total suspended solids (0,4 um filter)	<2	mg/l
Extractable organic chlorine	Volgt	mg/kg
Elements after digestion		mg/kg
- lead	1,55	-
- copper	1,07	-
- zinc	69,8	-
- nickel	<0,01	-
- chromium	0,05	-
- cobalt	0,25	-
- lithium	0,53	-
- manganese	1,27	-
- iron	24,3	-
- sodium	3930	-
- potassium	155	-
- aluminium	11,4	-
- tin	<0,01	-
- arsenic	<0,01	-
Cadmium (total, AA-HGA after digestion)(Q)	8,2	µg/l
Mercury (total, AA-CV after digestion)	0,6	mg/l

SWAB SURFACE ANALYSIS



Title : mmo2
 Instrument :
 Volt : 20,00 kv
 Mag. : x 850
 Date : 2023/08/15
 Pixel : 640 x 480



Acquisition Parameter
 Instrument : 6610 (LA)
 Acc. Voltage : 20,0 kv
 Probe Current: 1,00000 nA
 PHA mode : T3
 Real Time : 30,43 sec
 Live Time : 30,00 sec
 Dead Time : 1 %
 Counting Rate: 1486 cps
 Energy Range : 0 - 20 keV

ZAF Method Standardless Quantitative Analysis(Oxide)
 Fitting Coefficient : 0,2734
 Total Oxide : 24,0

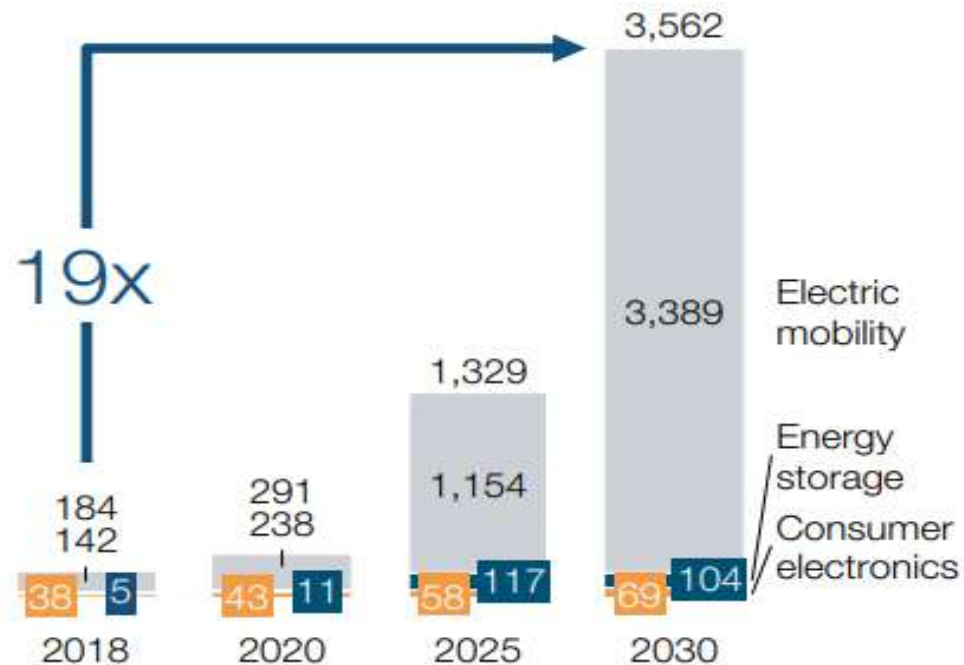
Element	(keV)	Mass%	Sigma	Mol%	Compound	Mass%	Cation	X
O		47,34						
Mg K	1,253	1,93	0,21	4,92	MgO	3,21	0,65	2,8003
Al K	1,486	7,32	0,40	8,39	Al2O3	13,84	2,20	12,3862
Si K	1,739	30,04	0,91	66,09	SiO2	64,26	8,67	55,0345
Ca K	3,690	13,36	0,41	20,61	CaO	18,70	2,70	29,7790
Total		100,00		100,00		100,00	14,23	

6. Looking to the Future – We need to change legislation

Market Developments and Considerations

Compared to today, global battery demand is expected to grow by a factor of ~19 to reach ~3,600 GWh in a 2030 target case

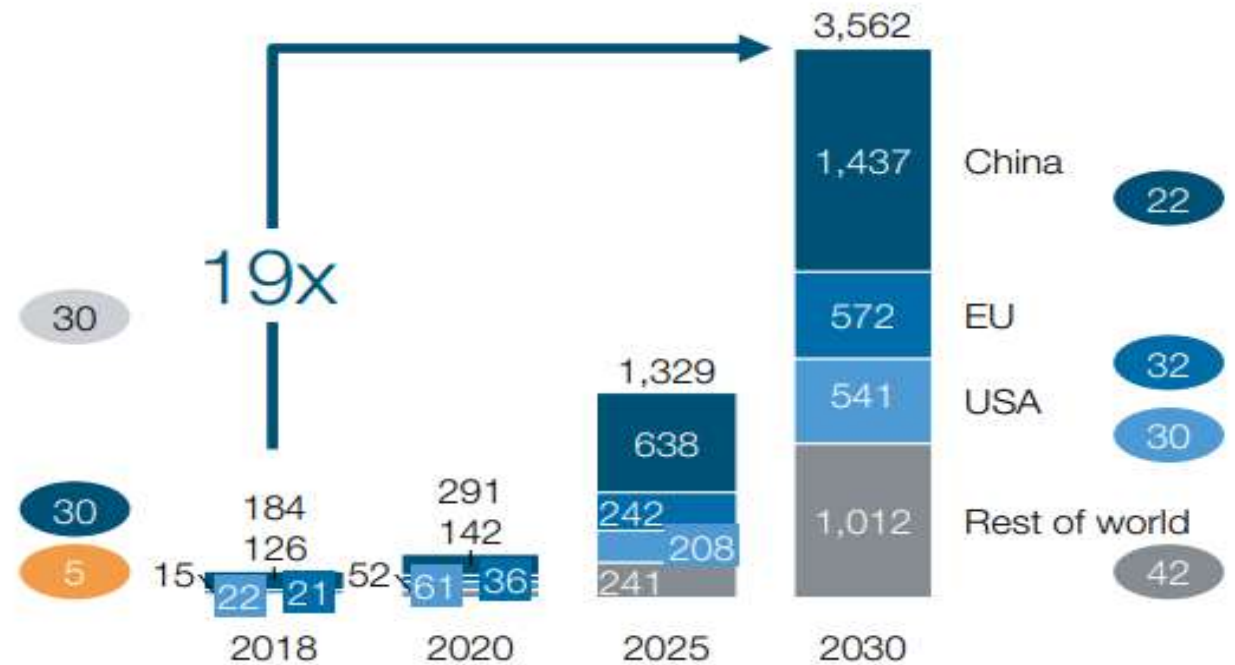
Global battery demand by application
GWh in 2030, target case



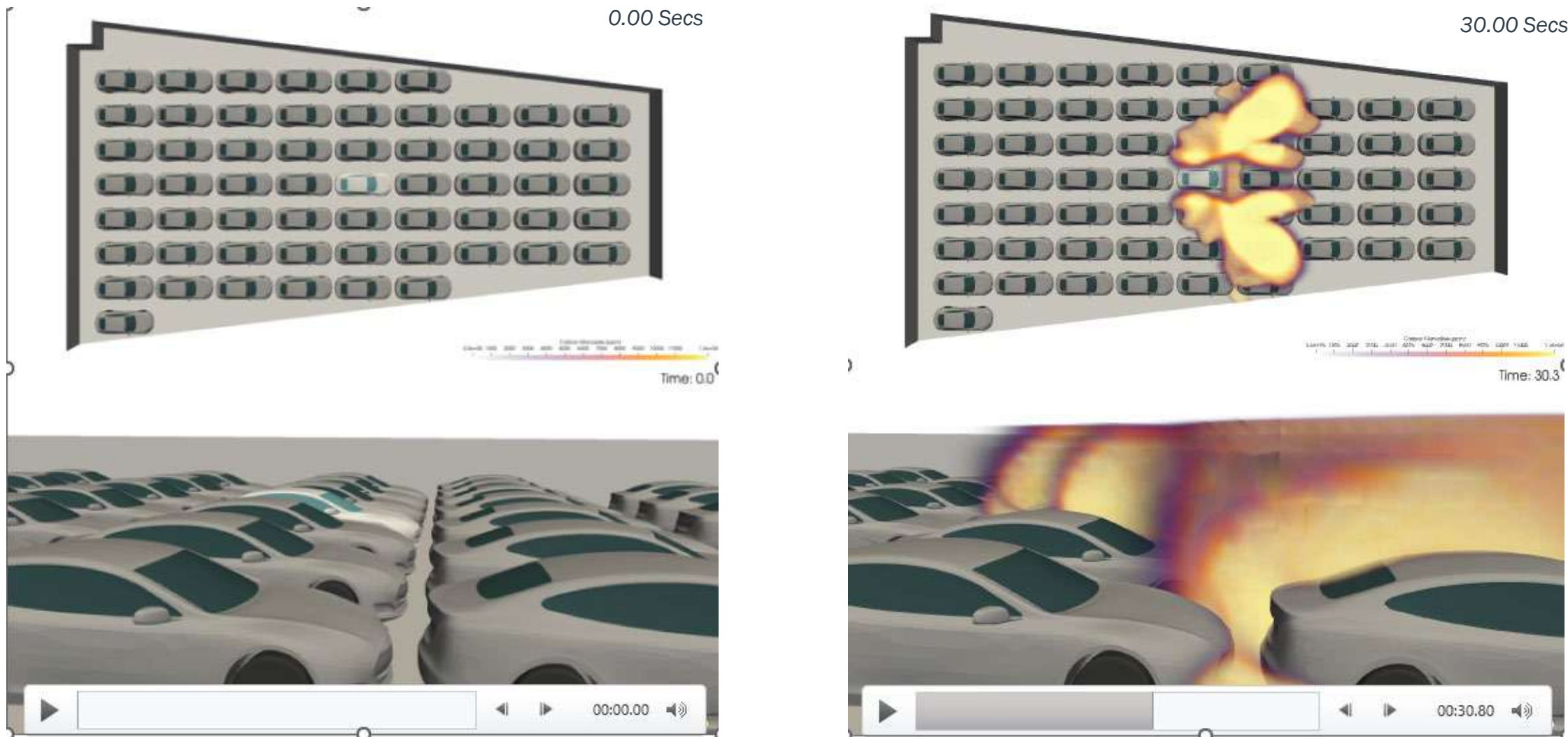
CAGR
% p.a.

Global battery demand by region
GWh in 2030, target case

CAGR
% p.a.



Using Technology to Try and Map Speed of Development of Vapour Cloud



BB, SMIT Salvage and REACT ERT are working on trying to replicate the fire development and spread using FEA modelling. This is an ongoing process but starting from findings obtained during recent incidents. This is to show the anticipated gas cloud production based on industry guidance of 6,000ltrs per 1Kwh and potential speed of development of the cloud around the vehicles in stow before any flames are introduced.

Potential additional PPE Equipment to perhaps be installed and supplied to vessels

DeWALT Mask Respirator

RS Stock No.: 250-5738 | Mfr. Part No.: DXIR1FFMMP3 | Brand: DeWALT



3M 6000 Series Full-Type Respirator Mask,

RS Stock No.: 286-7136 | Mfr. Part No.: 6700 | Brand: 3M



VanderPers:

Attached the filter type and explanation.

We recommend filter type Dräger RD40 combination filter A2B2E2K2HgCONOxP3.

This is also available from MSA in combination with a full face mask.

Since you also want to protect your eyes against possible acid gases and vapors

FILTER COLOUR CODING

Color	Filter Type	Main field of application
brown	AX	Gases and vapors of organic compounds with boiling point ≤ 65 °C
brown	A	Gases and vapors of organic compounds with boiling point > 65 °C
grey	B	inorganic gases and vapors, e.g. chlorine, hydrogen sulphide, hydrogen cyanide
yellow	E	Sulphur dioxide, hydrogen chloride
green	K	Ammonia
black	CO	Carbon monoxid
red	Hg	Mercury vapor
blue	NO	Nitrous gases, including nitrogen monoxide

Moldex 9000 Series Series Full-Type Respirator Mask,

RS Stock No.: 232-5894 | Mfr. Part No.: 9003 | Brand: Moldex



DRAEGER X-plore 6300 Series Full-Type Respirator Mask,

RS Stock No.: 221-8573 | Mfr. Part No.: R55800 | Brand: DRAEGER



VIKING FIREFIGHTER JACKET EXCELLENT

Prod. No.: PS1000 - Model 036

The VIKING firefighting jacket Excellent, is a short high performance jacket approved acc. to EN469. The jacket offers you protection and durability. With the VIKING design, you are sure to have the best possible mobility and superior fit.

- EN469 Reflective trimming
- Jacket without moisture barrier for good breathability
- Standard sizes available 46/48-66/68 ind short and long sizes
- Can be used with VIKING firefighter trousers Superior, item no. PS1050.548

[READ MORE](#)

Colour: Gold



7. The world we now live in...



And education of the public as well as seafarers to the potential hazards is essential



Standard extension lead led across floor of carpark in basement of office building – THE BB OFFICE BUILDING in LIVERPOOL...

Potential for short circuit or damage to cable leading to problems with vehicle battery is fully evident.

Unclear if there was a problem if the carpark fire installation (if any) would activate and prevent spread to building above.



THANK YOU FOR YOUR TIME



LITHIUM
BATTERY SAFETY RANGE

FIRECHIEF®
making the world a safer place



THIS IS OK



THIS IS NOT OK



NEVER CHARGE YOUR PHONE
IN OR ON YOUR BED!

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