

SWEDISH CLUB WEBINAR

Fire safety with electric vehicles onboard - Should we be worried?

**Franz Evegren, Magnus Arvidson
RISE Research Institutes of Sweden
2023-04-26**

RI.
SE

We are Sweden's
research institute





Research Institutes of Sweden

- Non-profit, 3 000 employees
- Department of Fire and Safety
- Test facilities in Sweden and Norway




BORÅS



**Large fire hall in
Borås, Sweden**

**18 m x 22 m x 19 m
HRR up to 15 MW**



New facilities for battery testing

Gothenburg 2023:
Heavy and light vehicles

Electric powertrain
Full scale vehicles

Nykvarn 2023:
Heavy vehicles

Electric powertrain
Hybrid transmission

Borås 2023:
Safety tests

Abuse cycling and cycling while
Climate, Vibration, Mechanical,
and Fire abuse testing



SEEL

SEEL Swedish Electric Transport Laboratory, är en del av RISE –
Research Institutes of Sweden och Chalmers University of Technology.

CHALMERS

RISE

Autoweek News • Industry News News Racing Car Life Opinion Podcasts

Felicity Ace Fire is Out But Why Do Car Carriers Have So Much Trouble?

There have been eight major incidents since 2002, half of them capsizings.

BY MARK VAUGHN FEB 23, 2022



TORSDAG 17 MARS 2022 (logga namn) Kontakt

START SPORT NOJE PLUS TV TIPSA KULTUR LEDARE

Schibsted Aftonbladet är en del av Schibsted. Schibsted är ansvarig för dina data på denna sida. Läs mer här

Tesla

Brand hos Tesla – sju bilar i lågor

Av Hans Osterman

PUBLISERAD: 20 OKTOBER 2020 | UPPDATERAD: 28 OKTOBER 2020

NYHETER

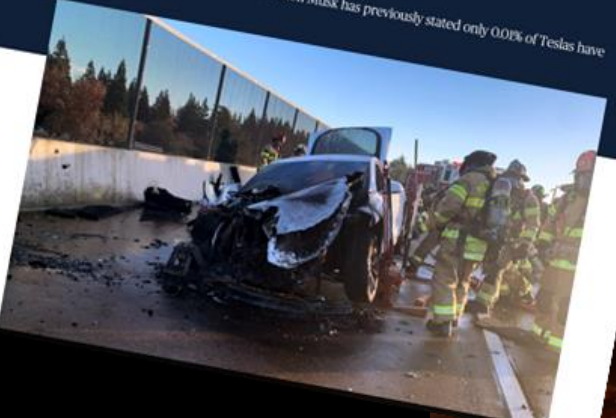
Branden på Teslas parkering började strax efter 01 under natten mot tisdagen. Sju bilar på en yta av mer än 300 kvadratmeter stod i lågor när räddningstjänsten kom fram. Polisen undersöker nu om gärningsmännen kan ha fastnat på övervakning.



NEWS POLITICS U.S. NEWS WORLD CULTURE AND TRENDS HEALTH BUSINESS TECH NBC NEWS TPLINE WATCH NOW

Tesla car battery 'spontaneously' catches fire on California freeway, requiring 6,000 gallons of water to put it out

No injuries were reported. Tesla CEO Elon Musk has previously stated only 0.01% of Teslas have ever caught fire.



BURNING EYES

ELECTRIC CARS HAVE ONE PROBLEM: THEY KEEP LIGHTING PEOPLE'S HOUSES ON FIRE

"IF WE HAD LIVED UPSTAIRS IN THIS HOUSE WE'D BE DEAD."




Summary of results from several RISE led projects

- **BREND** (2017-2019)
- **E-TOX** (2019-2020)
- **BREND 2.0** (2020-2022)
- **Safe and Suitable Firefighting** (2020-2022)
- **E-TOX 2** (2021-2022)
- **ACEA: Electric Vehicle Fire Safety in Enclosed Spaces** (2022)
- **LASH FIRE** (2019-2023)
 - Manual firefighting of BEV
 - Screening and management of AFV
 - Safe BEV charging onboard
 - Early detection of BEV fire/hazard
 - Early BEV fire suppression on vehicle carriers
 - Evaluation of presc. drencher on BEV



**Increased
knowledge in
BEV fire safety**



LASH FIRE

challenges:
accepted

Legislative Assessment for Safety Hazards of Fire and Innovations in Ro-ro ship Environment

Lash [lɑʃ]

verb strike forcefully against
bind down, secure, control

noun ...



Programme: H2020-MG-2018-2-2

Duration: Sept 2019 - Aug 2023

www.lashfire.eu

Call topic: Marine Accident Response, Subtopic C

Total Budget: 13.5 M€

Coordinator: RISE Research Institutes of Sweden

Instrument: Innovation Action (IA)



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 814975

Strategic objective



“To provide a **recognized technical basis** for the revision of international **IMO regulations**, which greatly **enhances fire prevention** and **ensures independent management of fires** on ro-ro ships in current and **future** fire safety challenges.”

20 challenges addressed

WP06 Effective Manual Operations		Cur	Fut	Reg.i	TRL	Validation
6-A	Manual screening of cargo fire hazards and effective fire patrols	C	F	R	6-7	Onboard/Terminal
6-B	Quick manual fire confirmation and localization	C	F		6-7	Onboard
6-C	Efficient first response	C			6	Onboard
6-D	Effective and efficient manual firefighting	C	F		6	Onboard/Field
WP07 Inherently Safe Design		Cur	Fut	Reg.i	TRL	Validation
7-A	Improved fire detection system interface design	C		R	5-6	Onboard/Virtual
7-B	Efficient extinguishing system activation and inherently safe design	C		R	6	Onboard
7-C	Firefighting resource management centre	C	F		6	Onboard/Virtual
WP08 Ignition Prevention		Cur	Fut	Reg.i	TRL	Validation
8-A	Automatic screening and management of cargo fire hazards	C	F		5	Onboard/Shore
8-B	Guidelines and solutions for safe electrical connections	C	F	R	6-7	Onboard
8-C	Fire requirements for new ro-ro space materials	C	F	R	6-7	Lab
WP09 Detection		Cur	Fut	Reg.i	TRL	Validation
9-A	Detection on weather deck	C		R	6-7	Onboard
9-B	Detection in closed and open ro-ro spaces	C		R	7	Onboard
9-C	Technologies for visual fire confirmation and localization	C			6-7	Onboard
WP10 Extinguishment		Cur	Fut	Reg.i	TRL	Validation
10-A	Automatic first response fire protection systems	C	F		5	Lab
10-B	Weather deck fixed fire-extinguishing systems	C		R	6	Onboard
10-C	Updated performance of alternative fixed fire-fighting systems	C		R	6	Lab
WP11 Containment		Cur	Fut	Reg.i	TRL	Validation
11-A	Division of ro-ro spaces	C			5	Lab/Onboard
11-B	Ensuring safe evacuation	C		R	6	Virtual/Shipyard
11-C	Safe design with ro-ro space openings	C		R	6	Virtual/Lab
11-D	Ro-ro space ventilation and smoke extraction	C		R	5-6	Lab/Onboard

LASH FIRE consortium



What are the greatest BEV fire hazards on ships?

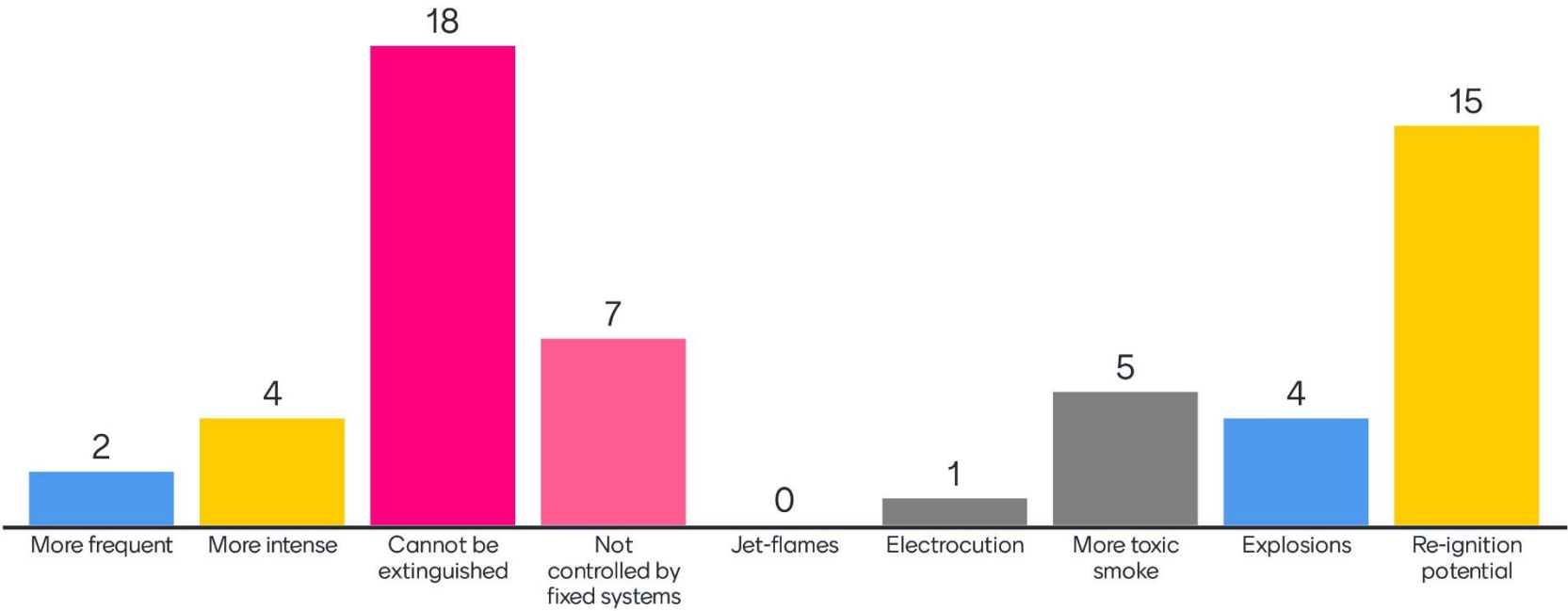
- ”BEV fires are more frequent”
- ”BEV fires are more intense”
- ”BEV fires cannot be extinguished”
- ”BEV fires are not controlled by fixed systems”
- ”**Jet-flames** will increase the fire spread from BEV”
- ”You risk **electrocution** when fighting BEV fires”
- ”BEV pose a higher **re-ignition potential**”
- ”BEV fires have **more toxic smoke**”
- ”BEV can cause gas **explosions**”

Go to www.menti.com

Use code: 5283 5398



What is the greatest BEV fire hazard on ships?



BEV fire frequency

Type	Total fires	Fires per 100k vehicles
Petrol/diesel	200 000	1 500
Battery electric	50	25

Data on car fires from the NTSB (Nov 2022), vehicle sales data from the BTS. <https://www.carsmetric.com/electric-car-fire-statistics/>

Why vehicle fires?

- Arson
- Engine compartment
- Overheated brakes



Fires per billion miles travelled

ICEV
55

BEV
5

ACEA study on Electric Vehicle Fire Safety in Enclosed Spaces 2022

- Fire frequency in Norway:
 - BEV population 2020: 17.3%
 - BEV fires (2016-2022): 2.3% (slight trend decline since 2018)
 - A factor 8
- Fire frequency in Sweden: Lower relative frequency of BEV fires by a factor ~10.
- Project report:
 - [Electric Vehicle Fire Safe in Enclosed Spaces](#)

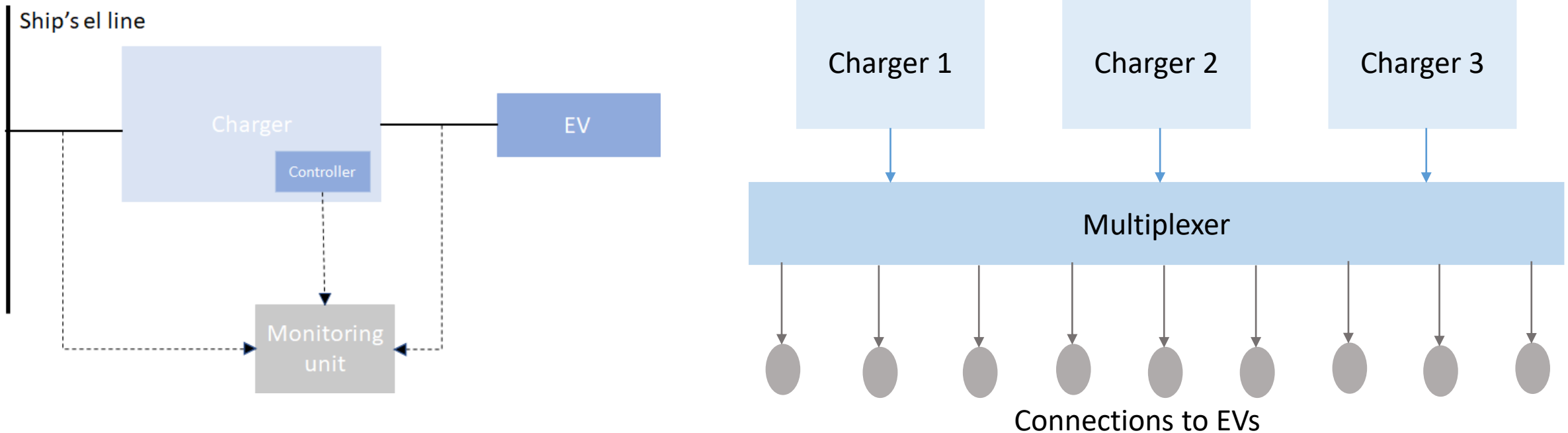


Will charging of lithium-ion batteries increase the risk of fire?

Thermal runaway causes:

- External shortage of battery pack/cell
- Internal shortage of cell
- Overcharge/Over-discharge
- Mechanical damage
- External heating

The LASH FIRE solution

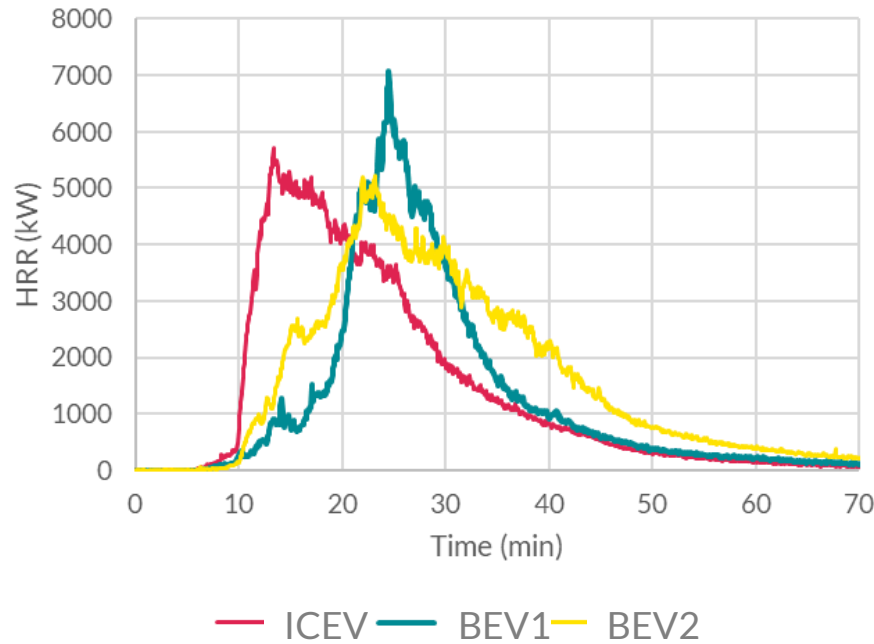


- A monitoring unit captures all measurable electrical parameters between the EV, the charging unit and the ship's main. Additional EV data from charger is a plus (Battery state of charge, charge request, etc)
- During charging, data are monitored in real time.
- Remote disconnection of individual cars is possible if needed.
- Charging solution to be at least a Mode 3 level.

Project report will be available soon at www.lashfire.eu

BEV fire intensity

Heat release rate (vehicle tests)



E-TOX 2019-2020

E-TOX 2 2021-2022

- Fire intensity:
 - Fire growth rate – not faster for BEV
 - Peak heat release rate – not higher for BEV
 - Total energy released – not higher BEV



90 kWh battery
~ 2 GJ



Plastics in cars
~ 3 - 7 GJ



- Project reports:
 - E-TOX: [Toxic Gases from Fire in Electric Vehicles](#)
 - E-TOX 2: [Investigation of extinguishing water and combustion gases from vehicle fires](#)

What are the greatest BEV fire hazards on ships?

”BEV fires are more frequent”

”BEV fires are more intense”

”BEV fires cannot be extinguished”

”BEV fires are not controlled by fixed systems”

-> Magnus!

”**Jet-flames** will increase the fire spread from BEV”

”You risk **electrocution** when extinguishing BEV fires”

”BEV fires have **more toxic smoke**”

”BEV can cause gas **explosion**”

”BEV pose a higher **re-ignition potential**”



Can fixed fire-extinguishing systems handle BEV fires?

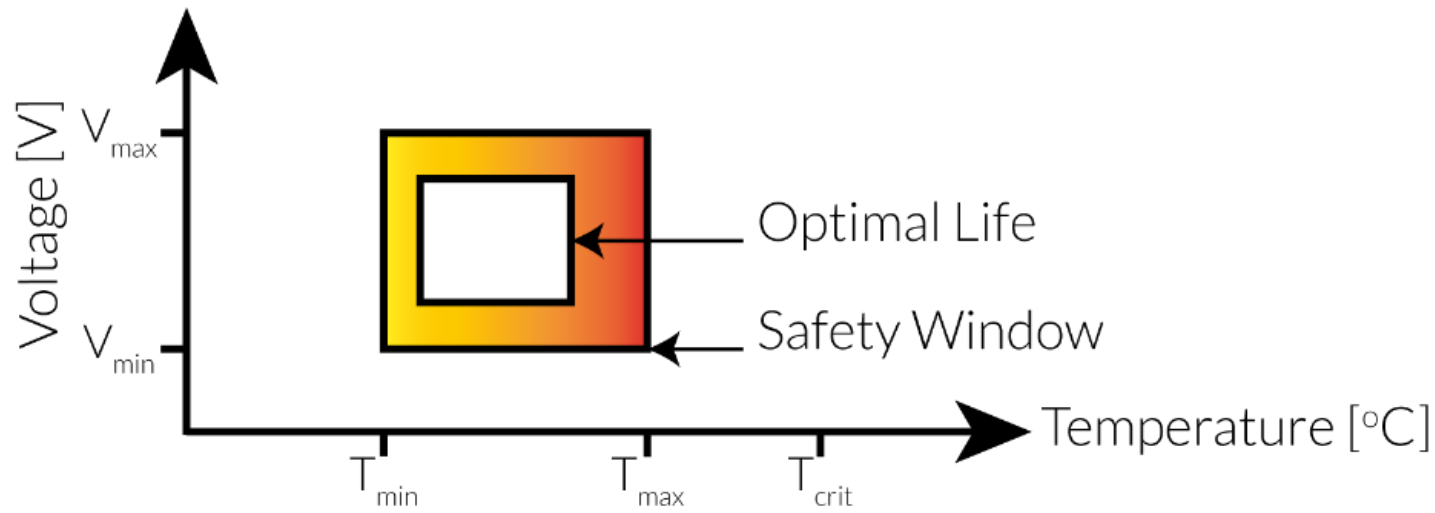
- Drencher – **YES**
- High-expanding foam – **YES**
 - Does not affect the thermal runaway.
 - Controls the fire.
 - Some questions remain, see documentation at www.kashiwa-tech.jp
- Carbon dioxide – **UNCLEAR**



Photo: Joel Blom, RISE

BEV fires cannot be extinguished

“Thermal runaway in a vehicle should be extinguished with a massive amount of water”



Upon cell failure, **heat from chemical reactions in one cell** can spread and cause chemical reactions in adjacent cells, **causing an escalation** referred to as **Thermal Runaway**. The temperature inside the battery increases rapidly as **toxic and flammable gases are generated** from chemical reactions in the cells. In many cases, the **gases released from the ruptured cells will also ignite, causing fire.**

BEV fires cannot be extinguished

“Thermal runaway in a vehicle should be extinguished with a massive amount of water”

An initiated thermal runaway **CANNOT** be extinguished from the outside. Stopping the TR requires cooling - very ineffective from outside the battery.

Propagation to undamaged cells **CAN** be hindered/slowed down, if sufficient cooling is provided – very difficult with current vehicle/battery designs.

Fog nails/extinguishing lances are **NOT recommended** for use in the engine compartment or **directly in the battery**



Will jet flames increase the fire spread from BEV?

What determines the fire spread?

- Distance between objects
- Heat radiation
- Petrol vs battery



Gas tank!



BREND 2017-2019

HAZARDS IN ADDITION TO EXPLOSION:

Liquefied compressed (LPG, DME) – jet flames will occur.

Compressed gas (CNG, H₂) – jet flames and TPRD should not be cooled.

Cryogenic liquid gas (LNG) – continuous venting.

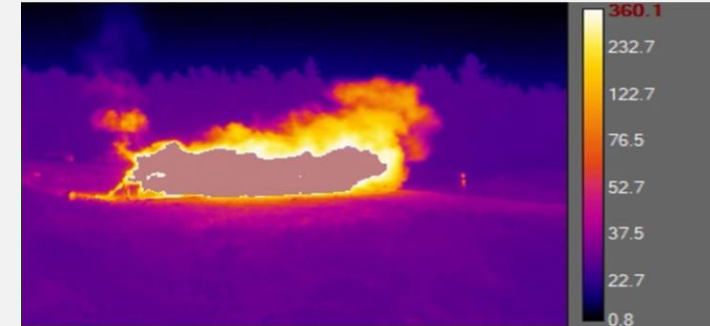
Batteries – manual extinguishment impossible and reignition risk.

- Strategy for firefighting of AFV in ro-ro spaces, based on literature study:
 - Activate fixed fire suppression system
 - Do not approach a burning electrical or gas vehicle - focus on cooling and hindering fire spread from a safe place.
 - Do not attempt to extinguish jet flames or other burning leakage of gases
 - Risk for explosion if TPRD of compressed gas tanks is cooled.
- Quick fire suppression and control is even more important with AFV – new tactics, methods and equipment were developed – see guideline in report!
- Project reports:
 - [Methods and equipment for firefighting with AFV in ro-ro spaces](#)
 - [Firefighting of AFV in ro-ro spaces](#)



BREND 2.0 2020-2022

- Fires from thermal runaway generally grow slowly, with low thermal exposure close to the fire for an extended period.
- Tanks with TPRD can be cooled with water from sprinklers or manual firefighting, without great risk for pressure vessel explosion – tests showed that direct cooling rather gave a positive cooling effect and more time until rupture.
- Jet flames are good! They prevent explosion, their duration is relatively short (normally <1 min) and their incident heat flux is relatively low, compared to flames from burning objects.
- Developed tactics: Cool the burning unit and prevent spread, but do not extinguish jet flames or burning gases. Training...
- During a vehicle fire in a ro-ro space, **ventilation** is the greatest single factor determining the toxicity (HF and other gases investigated, incl. FED and FEC dose). Regardless of type of vehicle, simulations showed that toxicity limits are much exceeded in a closed ro-ro space, while values were well below toxicity limits in well ventilated spaces, except close to the ceiling. Values were only slightly lower for ICEV than for BEV. Smoke is toxic.
- Project reports:
 - [Fighting fires in new energy carriers on deck 2.0](#)
 - [BREND 2.0: Fire simulation technical report](#)



Appendix A - Quick Guide

Quick guide: Fire in new energy carriers on deck

To improve the possibility of a safe firefighting operation in ro-ro spaces, it is important to know how to assess the risks with alternative fuel vehicles.

This quick guide is intended to increase the knowledge of risks related to fires in alternative fuel vehicles (AFVs) on board in ro-ro ships. AFVs include gas vehicles such as Liquefied Gas (LNG), H₂ or LH₂, and electric vehicles (EVs). The information is based on the results from the research project BREND 2.0, which focused on risks with gas vehicles and EVs in relation to firefighting operations.

Alternative fuel vehicles

Available statistics suggest that the likelihood of fires in AFVs is lower than for conventional vehicles. Both battery and gas vehicles are equipped with a range of safety systems, intended to protect them from fires.

These gases are known to combustion products for all types of vehicle fires. EV fires result in higher emissions of hydrogen outside of fire compared to internal combustion engine vehicles on fire. HF is very dangerous to inhale, but studies outside BREND 2.0 have shown that the risk for a potential skin uptake of HF is low. It is unlikely that adverse health effects are caused during smoke in-ro-ro from HF for firefighters wearing standard personal protection equipment.

Protective equipment and training

Research on the possible consequences of fires in electric and gas vehicles indicate that fire suits, approved according to EN 469 level 2 (together with gloves, boots, flash hood, long sleeve undergarments, and BA), provide a good protection against heat, fire, smoke, steam, and fire gases.

For a fast and efficient response, additional training routines are necessary. Not only the manual fire-fighting needs to be trained, also the activation of fixed firefighting systems (FFS) can be an issue causing concern by the crew. A combination of both approved and unapproved drills are useful. If the crew is often walking by their assigned mustering location when the fire alarm starts, occasionally unapproved drills can be a useful addition to the training routines. Consider the crew's familiarity when deciding if and how they carry out this type of drill.

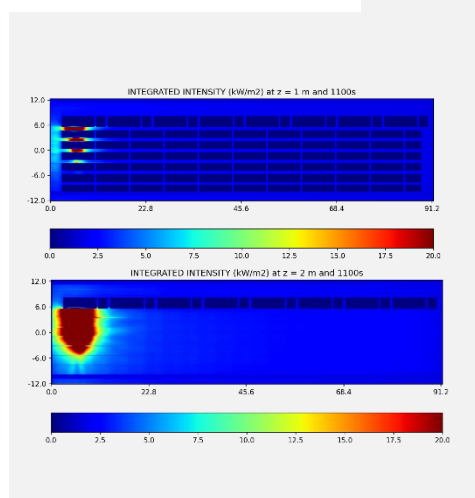
FIRES IN AFVs – TACTICAL RECOMMENDATIONS

Cooling of energy storage and quick extinguishment of vehicle fires lowers the risk of pressure vessel explosion, jet flames, and thermal runaway. However, different ships have different conditions. Is there a Fixed Firefighting system available? What is the size of the fire? What personal protection equipment (PPE) is available? The well-trained and confident in the crew? These are questions to consider when training and structuring the fire intervention. Depending on the possibilities for manual intervention and continuous risk assessment of the situation a defensive or offensive tactic can be taken.

- INITIAL FIRE STAGE**
Stay out of the smoke plume and, if possible, try to do so safely. Try to extinguish the fire while it is small. For example with hand-held fire extinguishers. Most likely there is no battery fire and no risk for pressure vessel explosion at this stage.
- ACTIVATE FIREFIGHTING SYSTEM**
If the initial fire cannot be extinguished, a deluge system should be activated (if available). This could be part of a defensive tactic where the fire is controlled using the deluge system. The crew can stay out of the fire to avoid until the fire burns out and any high-pressure compressed gas tanks have time to cool down. Monitor temperature evolution (e.g., at deck above fire or each temperature sensor) to verify that the fire is being extinguished or extinguished.
- FIRE TEAM INTERVENTION**
With an offensive tactic, initially, the AFV fire can be extinguished in a contained vehicle fire. Tractor battery will take long time to become involved and gas tanks are designed with a margin of safety in case of a fire. If possible, cool the energy storage (including tractor battery and gas tanks). As soon as compressed gas tanks are being cooled or not affected by the fire, they require a weight of safety against a pressure vessel explosion.
If there are jet flames from the tractor battery (below vehicles) or jet flames from gas tank a 100% face shield should be used. The firefighter should be positioned upwind and to the side of the fire. If possible and safe to do so, let the jet flames burn out.
- POST EXTINGUISHMENT**
Risk: Monitor the temperature and possible gas development for tractor batteries that have been exposed to fire. Intervention suppression equipment should be ready to verify control of re-ignition.
Note: Allow fire exposed gas tanks to cool down before the vehicle is approached. The tanks will re-ignite their original fuel and re-ignite material may be used to use a gas detector to verify. Monitor re-ignition gas through (LHG) in the smoke condition to look (check-off) risk. However, re-ignition gas should not be an issue in large or well-ventilated ro-ro spaces.

USEFUL LINKS

- [www.ris.se](#)
- [RIS and Sustainable Firefighting course 4 week guide](#)
- [International Association of Fire and Rescue Services](#)
- [https://www.iafrs.org/](#)
- [https://www.iafrs.org/iafrs-2020-2021-report](#)
- [https://www.iafrs.org/iafrs-2020-2021-report](#)



What firefighting should you do?

- Activate fixed fire-extinguishing system without delay!
- Manual firefighting to:
 - save life,
 - as a proactive measure,
 - to complement fixed system, or
 - post-fire control.
- Most fires do not initially involve the traction battery – generally requires about 30 min of fire exposure.
- The battery is only a minor part of the fire energy – you can still:
 - Extinguish the car fire!
 - Avoid fire spread!
- Water is a good coolant for vehicle fires, also for BEV. Water washes out gases from air, reducing toxicity and risk of explosion.

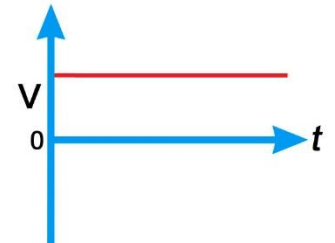


No risk of electrocution during BEV firefighting

Long, T. R. et al., *Best Practices for Emergency Response to Incidents Involving Electric Vehicles Battery Hazards: A Report on Full-Scale Testing Results*: 2013, NFPA



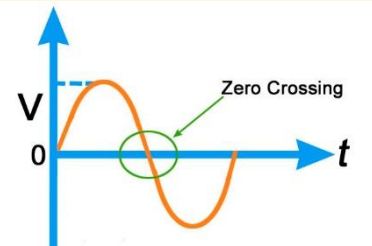
Battery: Direct Current



Current only travels between poles!

≠

Power grid: Alternating current



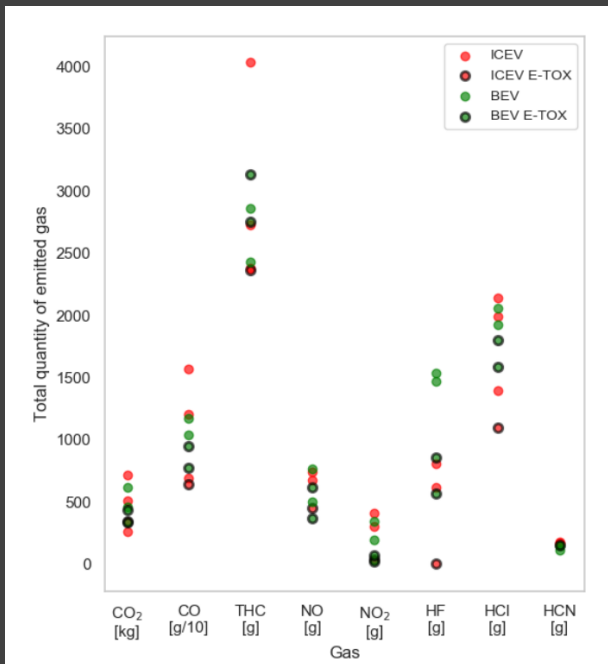
Current can travel to any earth!

Cut the power before extinguishing a charging vehicle!



BEV smoke toxicity

E-TOX



E-TOX 2019-2020

E-TOX 2 2021-2022

- There are several acute toxic gases released from both BEV and ICEV fires: CO, HF, HCl, HCN, SO₂, NO_x.
- HF represents the largest difference between EVs and ICEVs and, unlike other irritating gases, HF also has a systemic toxic effect and can be absorbed through the skin.
- Sprinkler had a large effect on HF concentration in smoke – HF “washed out”, but greater mixing of gases.
- Project reports:
 - E-TOX: [Toxic Gases from Fire in Electric Vehicles](#)
 - E-TOX 2: [Investigation of extinguishing water and combustion gases from vehicle fires](#)



From crew in user study:

"It's totally incomprehensible to me why the clothing worn by a smoke diver ashore isn't allowed for a smoke diver at sea. It is an obstacle for us to get hold of good equipment – especially at reasonable prices."

> Firefighter's outfit required by SOLAS

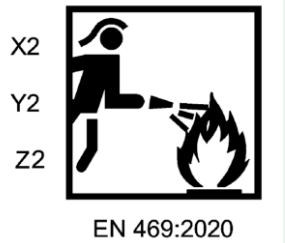


◀ MED/3.3b & 3.3c:
Firefighter's outfit with reflective surface
For protection against "intense radiant heat"

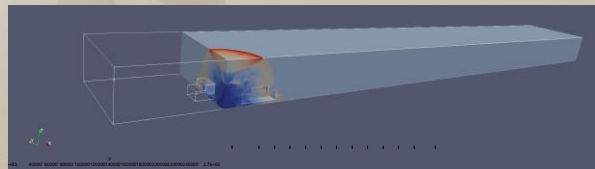


▲ MED/3.3a:
"Regular" firefighter's outfit.

Tested according to the same standard as land-based rescue service (EN 469). Comes in two levels, where level 2 is higher.



▲ The level is possible to identify by the pictogram included on the garment
X: Heat protection
Y: Water penetration resistance
Z: Breathability



Safe and Suitable Firefighting 2020-2022

- State-of-the-art firefighting gear protect well, but SOLAS requirements are outdated! EN 469:2020 level 2 should be required for firefighting onboard!
- With EN469:2020 level 2 suits, flash hood, second layer and BA, firefighters are well protected from all vehicle fire gases, including those of Li-ion batteries such as HF.
- Further recommendations: Type 2/3 footwear, lightweight cylinders, communication device for each smoke diver...replace axe?
- Maximum total exposure time in a toxic smoke environment is 40 min.
- All equipment that has been used in the fire and smoke should be treated as hazardous.
- Project report:

– [Safe and Suitable Firefighting](#)

BEV can cause gas explosion



Ignition vs explosion



95%

Ignition
Jet like, directional
flames



5%

Vapour cloud
explosion
Violent deflagration

Vapour cloud explosion

Of total vapour cloud explosion incidents:

70%

Underground /
enclosed space



30%

Open air



- Only relevant if there is no ignition, e.g. in case of a slow thermal runaway event.
- Needs further study!

Statistics from www.EVfiresafety.com, EV battery fire overview December 2022

BEV pose a higher re-ignition potential

- BEV must be monitored after fire suppression
- Do not remove firefighting equipment
- Cooling should continue until a safe return to port
- When in port, vehicle should be moved to safe location ashore



Summary

- BEV fires are not more common nor more intense than ICEV fires
- The fixed fire-extinguishing system should be started without delay and will suppress a BEV fire - if possible, keep it activated during manual intervention
- A thermal runaway cannot be stopped – firefighting should focus on controlling the fire and preventing fire spread, and potentially on cooling the battery.
- Fire effluents are toxic, both from ICEVs and BEVs, and should be fought with EN 469:2020 level 2 suits
- There is a higher re-ignition potential that must be handled.
- The BEV explosion risk has not been investigated.



Traditional fuels are potentially dangerous

- we have learned to handle them safely

Li-ion batteries are relatively new

Imply other hazards – we are still learning!

**RI
SE**



Check out our training videos!



LASH FIRE videos on YouTube:

https://youtube.com/playlist?list=PLi4tb8wkruNdRwLD525MQnC_zqx73-ZU6



LASH FIRE - EV Firefighting Film06 Post fire
33 visningar • för 7 dagar sedan



LASH FIRE - EV Firefighting Film05 Manual firefighting of gas vehicles
12 visningar • för 7 dagar sedan



LASH FIRE - EV Firefighting Film04 Fire Fighting Methods
23 visningar • för 7 dagar sedan



LASH FIRE - EV Firefighting Film03 First Response
8 visningar • för 7 dagar sedan



LASH FIRE - EV Firefighting Film02 Protection Suits
16 visningar • för 7 dagar sedan



LASH FIRE - EV Firefighting Film01 Introduction
76 visningar • för 7 dagar sedan



LASH FIRE - Webinar 'Fire on ro-ro deck'
293 visningar • för 2 veckor sedan



LASH FIRE - Tests on weather deck fixed fire-extinguishing systems
126 visningar • för 4 månader sedan



LASH FIRE - Interview with Calle Ortner, Safetygroups - Fire Safety Meet - DSM2022
41 visningar • för 7 månader sedan



LASH FIRE - Tests on fighting electric car fires
968 visningar • för 7 månader sedan



LASH FIRE - Tests on fighting electric vehicle fires: first response firefighting
2 506 visningar • för 7 månader sedan



LASH FIRE - Tests on fighting electric car fires: freeburn test 1
312 visningar • för 7 månader sedan



28 JUNE 2023
PULA, CROATIA

CFIS 2023
CONFERENCE ON
FIRE SAFETY AT SEA

register
now

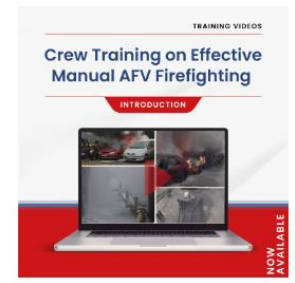
**Thank you for
your attention!**

Registration

CFIS2023 Agenda

CFIS2023 Attendee Kit

LASH FIRE is an international research project aiming to significantly reduce the risk of fires on board ro-ro ships. The project is running from September 2019 to August 2023.



Now available: Crew training videos on Effective Manual AFV Firefighting!
Alternative-fueled vehicles (AFV) represent different types of hazards compared with vehicles with traditional fuel such as gasoline and diesel with internal combustion engines. Do our usual methods, equipment, and training work, or do we need to do something more to be safe? Watch the LASH FIRE movies [here](#).



LASH FIRE Webinar – Fire on a ro-ro deck!
On April 5th 2023, LASH FIRE held a appreciated webinar on "Fire on ro-ro deck". Besides presentations and discussions on prohibiting carriage of BEV and sea-water drenchers we also had the chance to discuss fire-fighting capabilities and see a LIVE demonstration of extinguishment techniques.
[Watch the recorded webinar here.](#)



Short introduction to the LASH FIRE project
For a quick overview of the project and its objective, watch our short introduction animation [here](#). (2 minutes)



Funded by



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement n° 814975