FIRE ISOLATOR

FIRE RESEARCH ON EV- CAR FIRES

SAFETY ONBOARD FERRIES AND IN CARPARKS

FIRE SAFETY TESTING IN FREDRIKSHAVN

ATTENDANCE:

Mick Jensen, Studgaard Fire Safety AS, Denmark

Ron Verstegen, Nordic Sea Safe ApS, Denmark

Konstantin Toregozin, Garant Protech, Lithuania

Jan Peter Verheuvel, T-ISS BV, The Netherlands

Ib Steen Nielsen, Nordjyllands Beredskab Fredrikshavn, Denmark

Srdjan Rodic, Bullard GmbH, Germany

Location: Nordjyllands Testcenter (Beredskab), 15km north of Frederikshavn Denmark
Date: 18 November 2021

INTRODUCTION

Due to the increase of lithium-ion battery powered road vehicles the chances of spontaneous fires of these vehicles onboard ferries or in carparks are increasing day by day.

Lithium Fires are extremely difficult to extinguish and can cause huge collateral damages if not handled well.

There are many different types of lithium-ion batteries, with different packaging and chemistries but also variations in how they are integrated into modern vehicles.

In order to avoid in the best way possible collateral damages and dramatic catastrophes, specialists from across Europe gathered and discussed ways to successfully control EV car fires.

Several options were discussed, especially situations in Car parks and onboard ferries.

Meetings took place from April towards November which included practical testing of proposed methods.

T-ISS BV, Studsgaard AS & Garant Protech

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GENERAL INFO

This project was privately funded by the various partners, as listed in the attendance list.

The idea arose when the partners, who have long been experts in the Northern European ferry industry, received several questions from well-known ferry owners about how to deal with EV car fires while sailing.

As these experts knew already that Lithium fires are extremely difficult to extinguish, another and complete new concept was invented.

Instead of extinguishing the Lithium fire by any means necessary, it was proposed to isolate the fire to gain time to reach safety (e.g. a port), where a vehicle can be unloaded and stored in a safe place without additional damage to other cars.

The same idea is to gain additional time when an EV car fire occurs in an open air or underground parking garage.

START

A hazard identification workshop was held in Kiel, April 2021.

Here specialists identified the possible scenarios when an EV car would catch fire on a fully loaded ferry during the peak season.

We reflected on a diversity of scenarios. The focus of this workshop was "ensuring safety of passengers and crew aboard ferries and the effect of an EV car fire on the environment." Although many reports have been written, there was still no good way to deal with these situations.

One thing became clear, in case of an emergency situation, such as an EV car burning on a fully loaded car deck, it is essential to get to shore or safe harbor as quickly as possible.

After 2 days of gathering information, the conclusion was "Win as much time as possible!", at least 5/6 hours to get to a safe haven to remove all surrounding vehicles and carefully remove the EV burning car.

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1 INTRODUCTION

The use of EV vehicles is exploding around the world.

Figure 1 shows how the number of electric passenger cars in the Nordic countries compares to the rest of the EU according to the European Alternative Fuels Observatory. Together, the Nordic countries represent the largest electric vehicle market in the EU, with most purchases being made in Norway and Sweden (4).

The country that stands out the most is Norway. In 2018, about half of all passenger cars sold in Norway were electric (3). This is much higher than in other Nordic countries, where electric passenger cars sold in Sweden, Denmark, Finland and Iceland accounted for about 8%, 2%, 5% and 20% of all new cars sold in 2018, respectively (3).

(cc Rise report 2019)

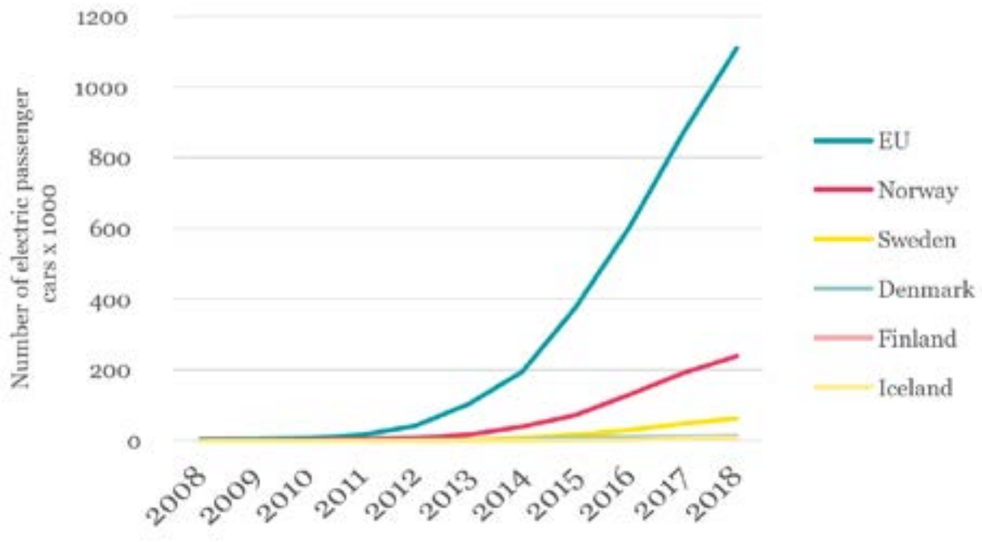

Figure 1 - The growth in electric passenger cars in Europe and the Nordic countries [3]

This project will continue to research and develop relevant risk management routines and evaluate fire extinguishing and emergency cooling systems, particularly on board ferries and in car parks.

Full-scale 1:1 situations will be conducted to evaluate whether they can improve safety when integrated into ferry and car park safety protocols.

As more EV vehicles become operational around the world, their involvement in traffic incidents is likely to increase as their presence on the road increases. The unwanted ignition or explosion of battery cells during charging is also a threat to the environment and surroundings.

In this test, we focus on how to deal with these situations when EV cars are in a car park or packed on cardeck of a ferry.

(cc Tripadvisor cars parked closed to each other on a ferry)

(cc Newgate-UK.com, cars parked close to each other in a underground carpark)

If an EV vehicle is parked on the cardeck during peak season, it will be among several cars that are close together and difficult to access. Once a fire starts at such a vehicle, it is extremely difficult to extinguish or otherwise approach.

The same is true of cars parked in underground spaces under buildings or at airports.

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2 THERMAL RUNAWAY

The main safety risk with LIBs is that of the individual battery cells that make up the battery pack. Misuse can release gas from the battery cell, which can ignite or cause an explosion. This can lead to an internal short circuit or increase in internal temperature by other mechanisms. The battery cell can then malfunction by releasing flammable gas, burn, explode, or become a projectile.

Thermal runaway is caused by a chain of chemical reactions within the battery resulting in an accelerated increase in internal temperature, which can reach 1300-1400°C.

The main battery hazards are usually the result of external or internal short circuits, high or low temperatures, overcharging or over-discharging. These mechanisms can lead to exothermic reactions within the battery. When the temperature becomes high enough, or when an ignition source is present that ignites the flammable gases released from the battery, the fire triangle seen in Figure 2. is completed.

Figure 2 - The fire triangle for lithium-ion batteries

3 CHALLENGES FOR FIRE FIGHTERS

Several tests have already been conducted by others (see Rise report 2019/50).

One of the purposes of these tests was to determine if there are any special requirements for firefighting operations with electric vehicles compared to conventional ICE vehicles.

TThe batteries were placed in relatively easily accessible locations in the vehicle: in the rear cargo area, either in plain view or under a replicated "floor plate." The firefighters noted that the biggest challenge was getting water to the fire site. They could cool the outside of the battery pack, but they could not reach the burning cells unless there was a way to spray the water into the pack. In 5 of the 6 tests, the fires reignited multiple times.

In terms of extinguishing operations, researchers have also found that the use of water as an extinguishing agent does not normally pose an electric shock hazard to firefighters.

Some tests found that a lot of smoke was released after the batteries were extinguished and recommended that a larger than normal area be cordoned off compared to an ICE vehicle fire.

Identifying Electric Vehicles

One of the biggest challenges for firefighters is identifying the type of vehicle they are dealing with, as it can be difficult to distinguish EVs from ICE vehicles due to their similar appearance. Knowing the type of vehicle they are dealing with is critical to making a good assessment of the associated hazards.

Firefighters must first determine whether the vehicle is an EV, Semi Hybrid, H2 car or a gasoline powered vehicle.

Gas emissions from lithium batteries are a concern for the safety of passengers in EVs, firefighters and other emergency personnel, and for the environment. This danger is increased when the vehicle emits gases in an enclosed space such as a car park or on board a ferry.

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Of most concern is hydrogen fluoride (HF), because it is already seriously irritating to humans at low concentrations and because significant amounts of HF have been found in reported fire tests.

HF is a toxic, corrosive, light gas that can penetrate some types of protective equipment.

An EV car fire produces huge amounts of HF gas or toxic smoke.

Water used for cooling or extinguishing was found to have elevated levels of fluoride and chloride.

It is important to take these hazards into account so that proper protective equipment can be worn, especially when handling damaged EVs.

(Picture 18-11-2021 Jan Peter Verheuvel)

4 COLLISIONS AND FIRES

Over the past decade, there have been several reports of LIB car fires.

Fires can be caused by charging, a collision, or for no reason at all.

A lithium battery can catch fire immediately or even hours after a collision or charging.

For electric vehicles, there is not only the threat of a fire immediately after a collision, but also the risk of a delayed battery event and fire that can affect towing and workshop operations. The sections below provide an overview of documented EV fire incidents, as well as an examination of available guidance and the risks associated with handling damaged EVs.

Below is a list of documented incidents:

Year	Location	Vehicle	Incident	Cause	Comments
2010	On Ferry "Pearl of Scandinavia"	Rebuilt Nissan Qash-qai	Fire during charging	Rebuilt Fiat 500	After the incident, the shipowner temporary forbid charging
2012	Sweden	Rebuilt Fiat 500	Fire during charging (after 25 hours)	Fire started in engine compartment, probably heater	
2012	New Jersey, USA	3 Toyota Prius & 16 Fisker Karma	Fire in vehicles immersed in seawater due to hurricane Sandy	Salwater	More than 2000 Toyotas (hybrid) not having a fire
2016	Ånge, Sweden	Tesla Model S	Fire during charging		Battery was not involved
2018	Rumpt, Netherlands	Jaguar I-Pace	Fire in parked vehicle	Maybe arsonist, battery not involved	One of the first I-Pace delivered

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5 GOAL

In order to consider the dangers that shipowners and owners of carparks, their crews and firefighters will face in the event of an EV fire, several tests have been conducted to determine if a fire can be extinguished or isolated for a certain amount of time.

If a fire cannot be extinguished, it is certainly a good thing if several hours can be gained to give a ferry time to reach a safe port to unload the vehicle and also to avoid collateral damage.

6 TEST SET UP

To see what dangers ship owners, carpark owners, their crews and firefighters are exposed to, several tests were conducted at a professional fire training center in Fredrikshaven Denmark.

1 **High temperature resistant fire blanket isolation test**

2 **Fire Extinghuiser & Aerosol Units Test**

3 **Combination Blanket & Aerosol Units Test**

4 **Temperature testing Normal & EV cars**

5 **Water extinguishing**

6 **Dip container test**

SPECIMEN, TEST LOCATION AND ATTRIBUTES

For testing purposes the location of Nordjyllands Beredskap site was chosen. Following cars have been used for testing.

Renault Zoe (EV), Seat Cordoba, Renault Fluence

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7 TESTS

1 High temperature resistant Fire Blanket test

As the main idea from the specialists was to find a combination of the use of a blanket in combination with an extinguishing agent, blankets have been tested against temperature.

Used was a VR0906Li fire blanket, temperature resistant up to a peak of 1600 °C.

A long-term test was done on a normal combustion vehicle, our Seat.

Here the temperature was around 500-600 °C.

Blanket could stand temperature without any defects except discoloring due to smoke

The same blanket was then used again on an EV with a burning battery, where the temperature rose to 1325°C for just a short period of time when the thermal runway of the batteries occurred again, the blanket easily withstood the temperature and kept the fire contained.

The blanket was reused from a normal car to an EV car. Best practice is to use a light colored blanket to detect damage, cracks or tears in the blanket.

The fire blanket can withstand very high temperatures but does not stand up well to sharp objects or overly rough handling of the blanket. The installation of the blanket must therefore be done carefully, without hard, jerky movements, so as not to damage the fabric or the loops.

After use, the blanket will discolor but can be reused if only used for limited period of time.

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2 Fire Extinguisher & Aerosol Units Test

Since the main idea of the specialist was to find a combination of using a blanket in combination with an extinguishing agent, we tried extinguishing the battery with the following agents:

1 Lithium Extinguishers
2 Aerosol Units

Lithium Extinguishers
Since there are so-called lithium extinguishers on the market we made several attempts to extinguish a burning battery of a Renault Zoe.

Result even after 6/10 attempts the battery started to burn again each time so we cannot call this a success.

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Aerosol Units

The use of so-called aerosol units has recently been introduced to the market and is already approved by SOLAS.

We tested the aerosol units, see photo 1, in a burning car (our Seat) and once the gas spread in the car, the fire was extinguished in seconds, which however caused a huge amount of smoke.

However after a while, when the gas had evaporated from the car, the fire started again. When used in combination with a blanket, the fire stays out for a long time.

Fire before

The fire 10 seconds after inserting the potassium salt aerosol units inside the burning car

3 Combination Blanket & Aerosol Units test

Since the idea behind the Fire Isolator was to use a combination of different equipment and tactics, we tested the use of the blanket and the aerosol units simultaneously.

When covering a vehicle with the VR0906Li blanket, the fire was isolated, and when a aerosol unit was inserted into and under the vehicle, the fire was under control for several hours.

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4 Temperature Testing Normal & EV Cars.

Specialist Rodic from Bullard visualized and compared the temperature range of a fire in a combustion car (gasoline, diesel) and an EV car.

1 Temperature range Combustion cars up to 600-700 °C.
2 Temperature range EV cars (our specimen) 700-800 °C with short bursts up to 1325 °C.

It is expected that when other EV cars burn with a larger battery pack the short temperature bursts will be more intense and for a longer period of time.

5 Water extinguishing

According to some theoretical literature, it should be possible to extinguish lithium-ion battery fires with water. We tried this with our test car Renault Zoe once it burned and the thermal runway of the battery also happened.

After 10 attempts of trying to extinguish the fire, we stopped due to the fact that after every 5 seconds after the fire hose stopped, the fire automatically reignited.

On a ferry or in a car park, water can only be used to cool the battery pack,or to keep the surrounding vehicles wet.

There is a method of including a water lance inside the battery pack once thermal runway from the battery pack has occurred, the water lance can then flood the battery from the inside.

However, on a ferry, or in a carpark, this will be very difficult to execute as it will take 2 firefighters to insert the lance through the floor into the battery from the inside before flooding it with water. It should also be taken into consideration that this would have to be performed in a car that is already in flames.

The photo below is from 20 seconds after we tried to extinghuish the car with water, this went on and on and on.

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6 Dip Container Test

Our EV, covered by the fire blanket, was still burning mildly after several extinguishing attempts. As has been practiced in several countries, EV cars can also be dumped into water-filled containers.

This test also used a modified container with special inlet and outlet for water.

The ditched car is harmless, nothing more happened except that the temperature of the water raised from 8 °C to 15 °C within an hour.

It is recommended that the car be left in there for 2 weeks. After this, the water is chemical waste and must be treated as such and disposed of in a manner prescribed by local authorities for the discharge of contaminated water.

8 CONCLUSION

It is extremely difficult to extinguish EV car fires, there is no doubt about that. Lithium fire extinguishers are useless for extinguishing EV car fires, but should be used on board for extinguishing laptop or cell phone fires.

Ferry owners should focus on getting to a safe port as quickly as possible when an EV fire occurs. At the same time, they should isolate the fire by trained personnel.

Carpark owners should focus on minimizing the collateral damage by deploying the Fire Isolator concept (fire blanket blanket and aerosol units), potentially even cover surrounding cars with the Fire Blanket. Until the fire department can safely remove the EV and submerge it in a container of water.

When a battery of an EV is still 'only' heating up or there are no big flames yet, the Fire Blanket could be installed by 2 people without any protective gear. When flames are visible, the use of protective gear is advised.

The Fire Isolator concept can isolate the fire in a short time with a combination of blankets and aerosol units. The blankets should always be light in color so that anyone can easily see damage such as cracks or tears in the blanket. There should be a procedure for handling EV car fires on board ships, specialists have already established a training program for this.

Training in covering cars with blankets and using Aerosol Units and other relevant equipment is of utmost importance to have the best chance of a good result and prevent as much collateral damage as possible.

To prevent additional damage on board a ferry or in a car park, surrounding vehicles need to be protected, which can be done quite easily, by covering the cars parked next to the burning with fire blankets as well.

Once a fire is isolated, it must be continuously monitored until the ferry safely reaches the closest port where the EV car can be unloaded or, in case of an EV fire in a carpark, untill the car can be safely removed by professional intervention services. A thermal camera with a temperature range up to 1500C should be used for monitoring.

Ports should be equipped with ditch containers, these containers should be 75% filled with water when the ship arrives and the EV car should be dumped there and left for 2 weeks. In car parks the situation is a bit different, of course you are not at sea, but there are other dangers.

The opinion is that in the future the layout of parking garages should be adjusted so that there are no more than 3 or 5 cars next to each other, so that in the event of an event only these 3 or 5 will be damaged. Furthermore, it is strongly recommended that blankets be stored in closets on each level and that local firefighters/fire vehicles be equipped with aerosol units.

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9 REFERENCES

Anyone involved in fire protection and extinguishing EV vehicles is advised to read this report, because it contains very specific and useful information.

Rise Sweden report 2019/50
Research Institutes of Sweden AB RISE Report 2019:50
ISBN: 978-91-88907-78-3
Borås 2019. Fire Safety of Lithium-Ion Batteries in Road Vehicles Roeland Bisschop, Ola Willstrand, Francine Amon, Max Rosengren

Appendix A, Participants of Test

The participants of the hazard inventory workshop are introduced below.

Participants	Organisation	Profession/Competence and Role
Ron Verstegen	T-ISS	Expert in fire safety escape on ferries
Mick Jensen	Studsgaard	Senior expert in firefighting on ships
Konstantin Toregozin	Garant protec	Expert in supply installation fire safety on ships
Ib Steen Nielsen	Nord Jyllands Beredskap	Senior Fire Fighter
Srdjan Rodic	Bullard Gmbh	Expert in Thermal Camera
Henrik Hensen	Nord Jyllands Beredskap	Fire Service
Annette Robck	Nord Jyllands Beredskap	Fire Coordinator
Alan Gardex	Nord Jyllands Beredskap	Fire Specialist
Brian Studsgaard	Studsgaard	Testing Specialist
Jan Peter Verheuvel	T-ISS	Imaging

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