Attachment 2 – Findings of the EV FireSafe Study

Relevant to the "Solar Electricity and Battery Storage Systems Safety Handbook for Firefighters"

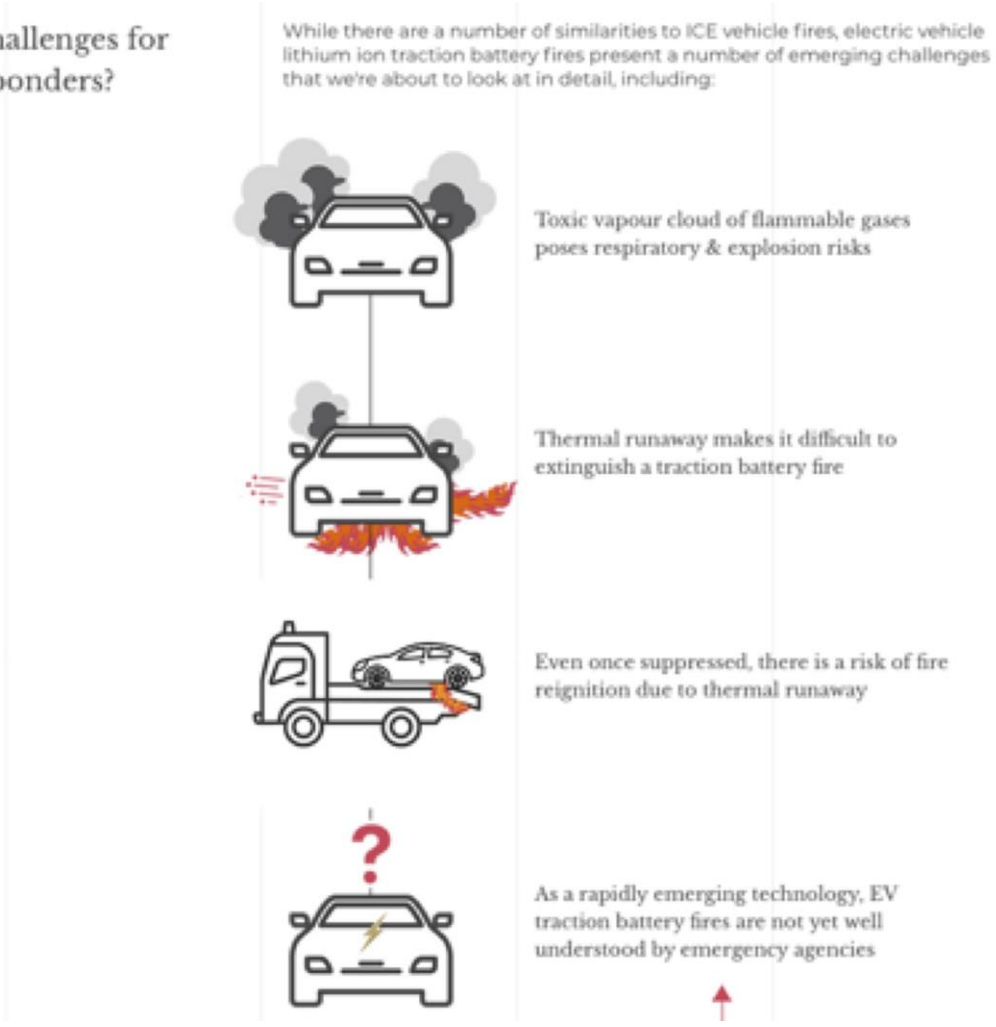
EV FireSafe – Defence Science and Technology Group, Australian Government, Department of Defence

https://www.evfiresafe.com/

Enhancing safety for emergency responders at *electric vehicle* traction battery fires

EV FireSafe is a private company that received seed funding from the Australian Department of Defence to research electric vehicle high voltage battery fires & emergency response, particularly where the EV is connected to energised charging.

https://www.evfiresafe.com/ev-fire-key-findings



02.3 What we know (so far)

Here's what our research found & what we learned from the experts*

There's a lot yet to be discovered regarding electric vehicle lithium traction battery fires - referred to here as 'traction battery fires' - but we've collated a list of the facts we think it's important for emergency responders to know now.

- **Electric vehicles are less likely to catch fire than ICE vehicles**
    a. Studies are ongoing, but evidence suggests a traction battery is less likely to ignite than ICE vehicles.
    b. Jump to EV Fire FAQs

- **Thermal runaway is how all EV battery fires start**
    a. When a battery cell experiences a short circuit, thermal runaway may occur.
    b. Jump to Thermal Runaway

- **A battery under 50% charged is less likely to ignite**
    a. Testing shows that a traction battery with a state of charge (SoC) of under 50% is less likely to ignite.
    b. Jump to Thermal Runaway

- **An EV lithium traction battery burns hotter than an ICE vehicle**
    a. A burning ICE car may reach 815-1000 degrees Celsius, an EV up to 1200 degrees Celsius.
    b. Jump to Risks - EV fires overall

- **Fire behaviour is different & presents new challenges**
    a. Recognising an EV by vapour & fire behaviour assists in early identification & management of the incident.
    b. Jump to EV Fire Behaviour

- **It's not smoke, it's a vapour cloud of highly flammable gases**
    a. When thermal runaway occurs, large clouds of flammable gases are released, primarily hydrogen.
    b. Jump to EV Fire Behaviour

- **Water is the most effective way to extinguish an EV battery fire**
    a. Lots of water to cool the battery & suppress flames is required; at least 4000 litres should be established.
    b. Jump to Suppression Methods

- **EV traction battery fires may require more resources**
    a. A longer suppression time may mean additional people, appliances & water.

- **The location of an EV battery makes fire harder to extinguish**
    a. A traction battery, located along floor pan, means the vehicle may need to be jacked up to apply water.

- **Risk of electrocution via water stream is lower than expected**
    a. An EV is not earthed, presenting low risk when using an unbroken stream of water to suppress fire.
    b. Jump to Risks - EV fires overall

- **Electrocution risk from HV cables is lower than expected**
    a. Orange cabling & components indicate high voltages, from 400V, & can pose a risk if damaged or exposed.

- **A submerged EV does not electrify a body of water**
    a. An electric vehicle underwater does not cause surrounding water to become electrically live.

- **Best practice; allow a traction battery to burn out**
    a. If location & time allow, there is a lower risk to all responders in letting the battery completely burn.
    b. Jump to EV fire reignition

- **EV traction battery fires can reignite, hours or days later**
    a. If it's not possible to allow the traction battery to 'burn out', re-ignition risk should be considered.

04.10 EV battery fire suppression

How do firefighters put out an EV battery fire?
Due to the self-sustaining nature of thermal runaway, we've moved away from using the word 'extinguish' in relation to lithium-ion battery fires and instead prefer to discuss how we suppress & contain them.

We're going to break this page down into three parts:
- Best practice methods
- Challenges of EV battery pack designs for firefighting
- Products coming to market

What are the best practice methods for putting out an EV battery fire?
There is no one method to manage an EV battery fire, rather three methods used globally that have emerged as best practice; Cool, Burn, Submerge.

Each of these EV fire incident management methods are valid options for suppressing & containing an EV in thermal runaway. The Cool or Burn options do not require fire agencies to purchase or use additional tools, which may be cost prohibitive or difficult to carry.

Cool
Burn
Submerge

EV battery fire suppression - cool

Use fog nozzles to knock down flames & provide cooling jets onto battery pack exterior to cool down the exothermic reaction of thermal runaway.

Pros:

- Recommended by all EV manufacturers
- Firefighters are 'seen' to be doing something by public

Cons:

- Doesn't get water where it needs to be
- Like 'putting out a kitchen fire by spraying water on the roof of a house'
- Water usage may be in excess of 10,000 litres *to extinguish a single EV (a typical fire department water tanker can carry 15,000 litres of water)*
- *The Tara Shift Solar BESS is rated at 1600 MWh, equivalent to 16,000 to over 26,000 Tesla EV's*
- Run off will need to be monitored & captured, particularly near waterways

Case study:

A plug-in hybrid EV was accidentally submerged in salt water at a boat ramp, with thermal runaway following removal, which was knocked down by firefighters, & secondary ignition occurring while being towed. Crews used two hose lines to cool the battery pack for an extended period. 15th May 2020, Port Moody, Canada

EV battery fire suppression - burn

Allow the lithium-ion battery pack to burn itself out, hot & fast.

Pros:

- Recommended by some EV manufacturers *(was the recommendation for the Australia Tesla BESS Fire)*

Image credits Fire Rescue Victoria

- *This Australian fire* in 2021, *affected 2 units of a 212 unit Tesla Megapack-based energy storage project in southeastern Australia. It burned for four days, prompting local authorities to send 150 firefighters and more than 30 fire trucks to the scene.*
- *This was a 300 megawatts/450 megawatt-hours capability battery. (Versus the 400 MW, 1600 MWH BESS approved by IESO for Tara, Ontario, some 3½ times larger)*

- Burns through majority of live cells, leaving scrap metal
- Removes stranded energy & secondary ignition risk

Cons:

- Time to burn will depend on battery size, state of charge, ambient temperature & other factors
- Air quality risks - monitoring & warnings for surrounding exposures
- Public / media attention; 'why aren't firefighters DOING something?'

Case study:

An EV went into thermal runaway while fast charging. The fire department opted to let the battery burn out. It was flipped onto it's side for easier monitoring with a thermal imaging camera. Time taken to burn is unknown. 22nd April 2022, Berlin, Germany.

EV battery fire suppression - submerge

Submerge EV in a containment unit that can be filled to pack level with water.

Pros:

- Contains fire spread
- Manages incident relatively quickly
- Firefighters are 'seen' to be doing something by public

Cons:

- Containment units may not be available or in close enough proximity
- Water usage may be in excess of 10,000 litres
- EV may need to remain in water for days/weeks
- Thermal runaway will continue underwater
- Time for thermal runaway to conclude depends on battery capacity & state of charge
- Water will need to be treated for disposal which can be expensive

Case study:

An EV went into thermal runaway with off-gassing, but no visible flame, while at the dealership. Fire crews organised a containment unit & the EV was submerged for several weeks. 25th March 2019, Tilburg, Netherlands.

What are the challenges of suppression using the Cool method?

There are two main challenges with firefighting an EV battery fire: position & access.

The position of the EV battery pack makes firefighting difficult:

We previously looked at how a traction battery is constructed, & how (in most EVs) it is positioned along the floor pan of an electric vehicle, between chassis rails.

If the battery pack goes into thermal runaway, the position means:

- It's difficult to locate the area in the pack thermal runaway is occurring, either visually or with a thermal imaging camera (TIC)
- Spraying water onto the outside of the pack to cool it often means firefighters have to be close to the vehicle & risk exposure to jet like flames

Lithium-ion battery pack underneath an electric vehicle

It's usually impossible to get cooling water onto the battery cells:

The construction of an EV battery pack where individual lithium-ion battery cells are contained

within a module, & modules within the pack, means getting water where it needs to go to cool the cells is almost impossible.

However; we are aware of some cases where an EV has been involved in a collision, & firefighters were able to direct water into the pack where it had torn open, to directly cool the battery cells. This is safe to do & does not carry the risk of electrocution (unless the EV is connected to energised EV charging).
Cells & modules are contained within a pack, which is IP rated & essentially waterproof

What about extinguishment or suppression products?
As with all emerging industries, a range of products claiming to 'extinguish' EV battery fires are being aggressively marketed to both fire agencies & the private sector as the answer to EV battery fires.
We are often asked whether a fire agency should buy a fire blanket, cutting tool or extinguishing agent, & our answer is; no, there is no need to purchase extinguishing tools for EV battery fires.
While this response does not make us popular with those manufacturers, currently (as of 2024):

- EV battery fires are rare
- These tools are typically very expensive
- They may be too large & heavy to be comfortably carried on a truck
- Often come with no manufacturer operating procedure or training

It should also be noted that some of these products may actually increase risk to emergency responders, even when being used correctly.

Having said that, there are some scenarios in which these tools may be useful, & all considerations are outlined in the comparison table here.

Fire blanket
Fire extinguishers
Cutting tools
Underbody sprays

EV battery fire suppression - fire blankets
Large thermal fire blanket that is placed over an EV to contain flame.

Pros:

- If used in time, blanket will contain flames & stop fire spread to exposures
- Can be left on EV as it's moved from scene

Cons:

- ~25kgs for one car-sized blanket, so must be used by two firefighters in breathing apparatus
- Cannot 'extinguish' or stop thermal runaway (despite manufacturer claims!)
- Thermal runaway will continue under blanket & may slow down (as opposed to the Burn

method), the process Vapour cloud (off-gassing) will continue under the blanket
- More independent testing is required to ensure efficacy & safety for responders

Increased risk:
- Where a blanket is lifted by wind or a person, the build up of gases under the blanket may cause a localised vapour cloud explosion
- Blankets often come as single or multi use, but there are no agreed, safe decontamination procedures for multi-use blankets

For responders:
- We do not consider it necessary to buy & make space on a truck for a fire blanket for the sole purpose of EV battery fire management at this time
- Where blankets have been purchased by a high-risk site, fire blankets should be used with caution to avoid causing vapour cloud explosion
- As most thermal runaway events occur prior to fire crew arrival, fire blankets will typically be most useful post-incident to contain a potential secondary ignition

For private sector businesses:
- Sites where EVs are parked, stored or charged in normal operating conditions do not require fire blankets
- Higher risk sites such as where EV or lithium-ion battery repairs, servicing or manufacturer occur may consider purchasing a fire blanket, but;
- A standard operating procedure should be sought from the manufacturer or written by the site, including:
  - NO staff should be trained to cover an EV in active thermal runaway due to high risk of injury or death
  - Blankets should be used by attending fire crews only