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Spontaneous Ignition of Electric Vehicles After Immersion in Water

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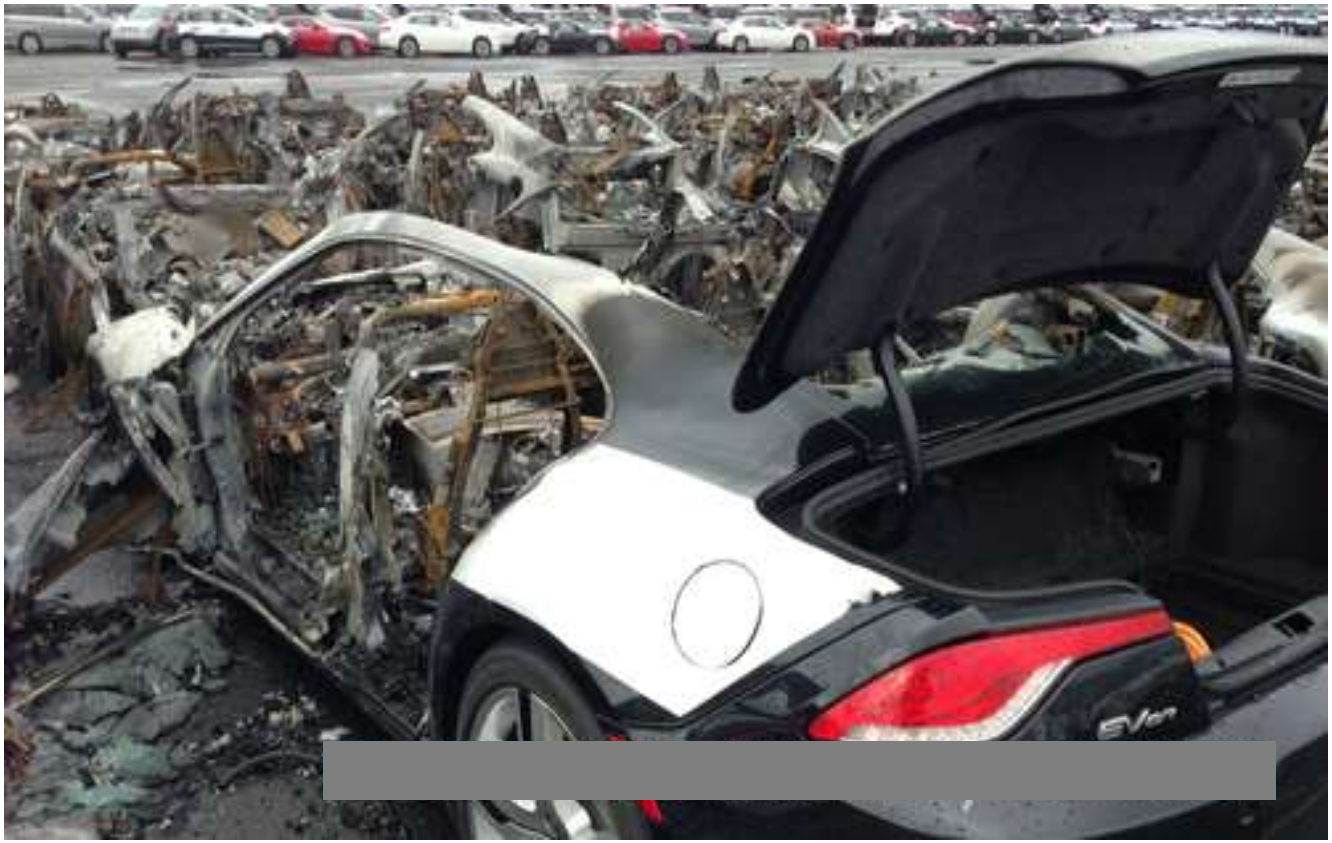
Introduction

- eBuses are rapidly becoming a major form of transportation in China as the country moves to reduce pollution and reliance on fossil fuels
- Over xMillion people in China ride on eBuses every day and rely on it as their principle form of transportation
- eBuses must be both cost-effective and safe to accomplish this mission since they carry numbers of people on one vehicle
- YouLion is a major producer of Li-ion cells and packs for the eBus market and is striving to address not only cost, but safety in eBuses
- This talk addresses a previously unidentified threat to eBus safety

Safety Incident: 16 Fisker Karma PHEVs Unexpectedly Caught Fire After Immersion in Sea Water during Hurricane Sandy



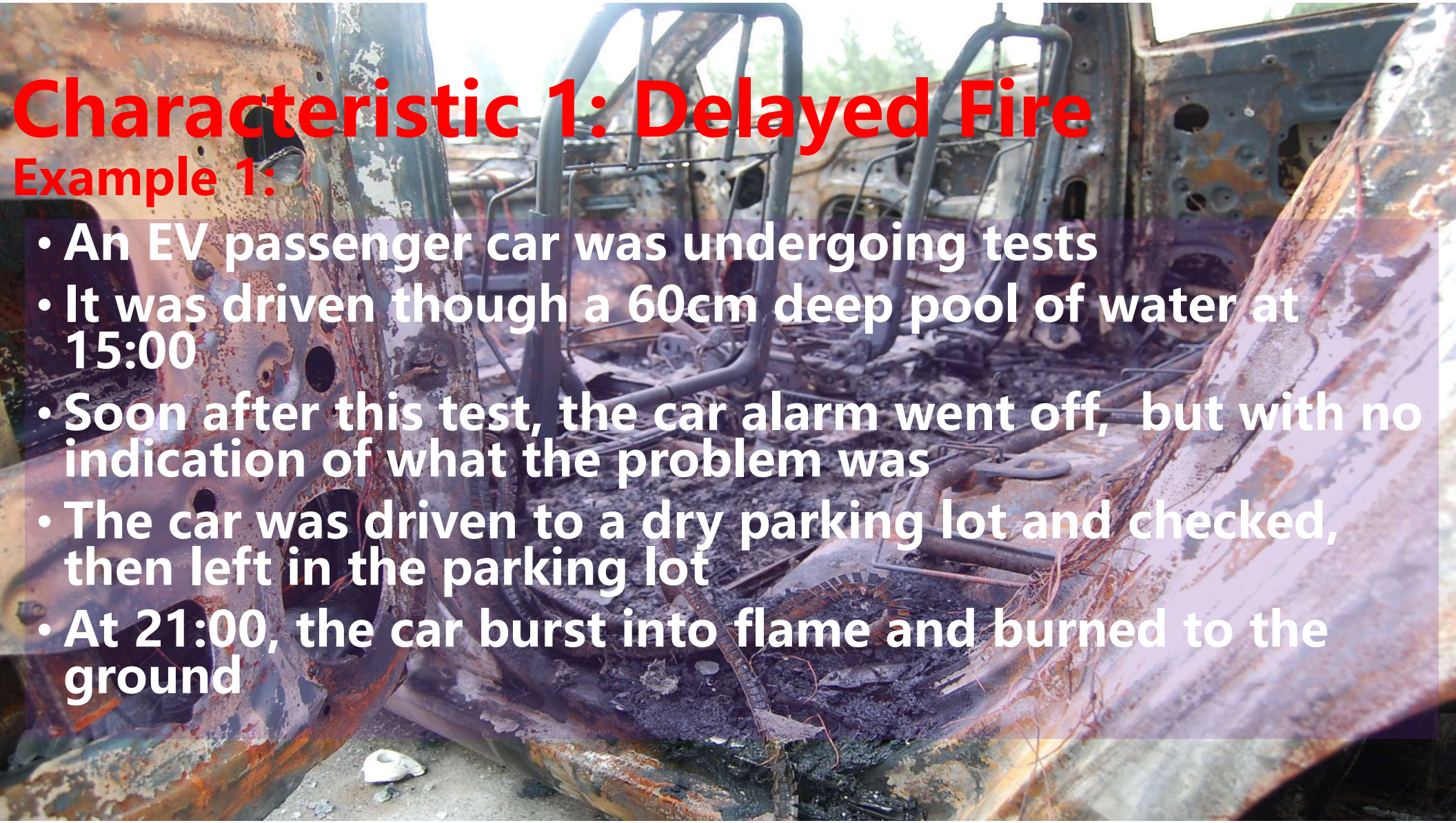
Approximately 16 of the $100,000+ Fisker Karma extended-range luxury hybrids were parked in Port Newark, New Jersey last night when water from Hurricane Sandy's storm surge apparently breached the port and submerged the vehicles. As *Jalopnik* has exclusively learned, the cars then caught fire and burned to the ground.

Safety Incident: July 2016, City eBuses Caught Fire After Water Immersion during Heavy Rain in Nanking, China

Safety Incident: July 2016 Mini eBuses Caught Fire After Water Immersion during Heavy Rain in Suzhou, China

Video of Bus Fire and Explosions

A city bus wades through deep water and driven to indoor packimg, caught fire 20 hours later



Characteristic 1: Delayed Fire

Example 1:

- An EV passenger car was undergoing tests
- It was driven though a 60cm deep pool of water at 15:00
- Soon after this test, the car alarm went off, but with no indication of what the problem was
- The car was driven to a dry parking lot and checked, then left in the parking lot
- At 21:00, the car burst into flame and burned to the ground

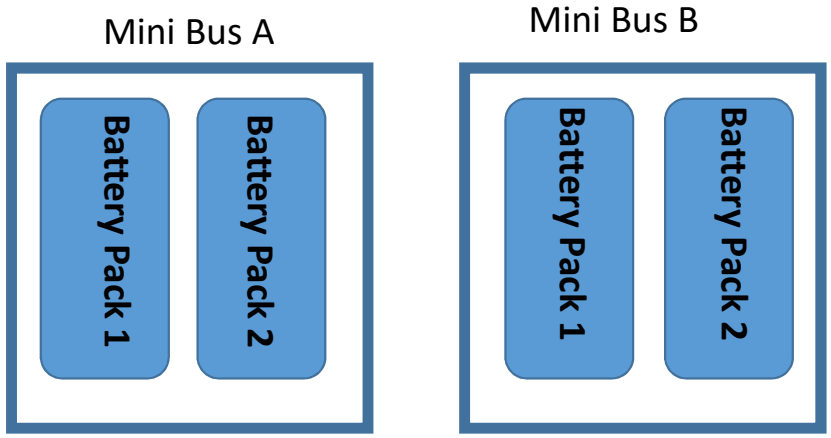
Characteristic 1: Delayed Fire

Example 2

- In 2016, Two Electric mini buses were parked in a lowland parking lot
- The mini busses were soaked in water after a heavy rain and failure of a nearby sewage system.
- The rain stopped at 4:00 am
- At 6:00 pm the same day, the first mini-bus spontaneously caught fire and burned
- At about 5:00 am the next day, the second mini-bus burst into flame
- After 7 days on dry land, the first mini-bus caught fire again and burned
- It was confirmed that both mini buses were equipped with 2 Li-ion battery packs each

Characteristic 1: Delayed Fire

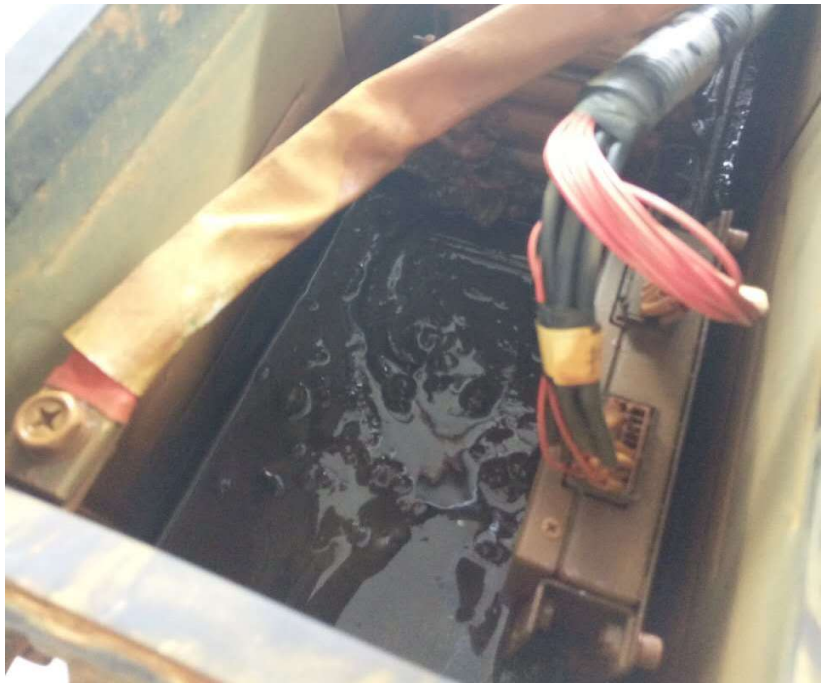
The sequence of fire for 4 battery packs after immersed in water



Heavy rain stops at 0 hour
Mini bus A, Battery Pack 1 caught fire at 14 hours after the rain
Mini Bus B, Battery Pack 1 caught fire at 25 hours after the rain
Mini Bus A, Battery Pack 2 caught fire at 182 hours after the rain
Mini Bus B, Battery Pack 1 never caught fire

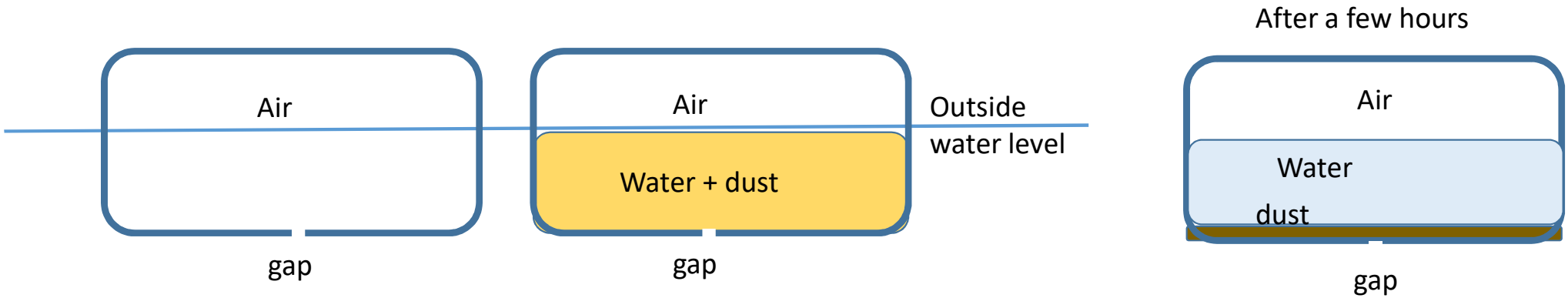
Characteristic 2: Gas Production

Bulged steel cases after sustained immersion in water



Mud and water found inside the steel cases

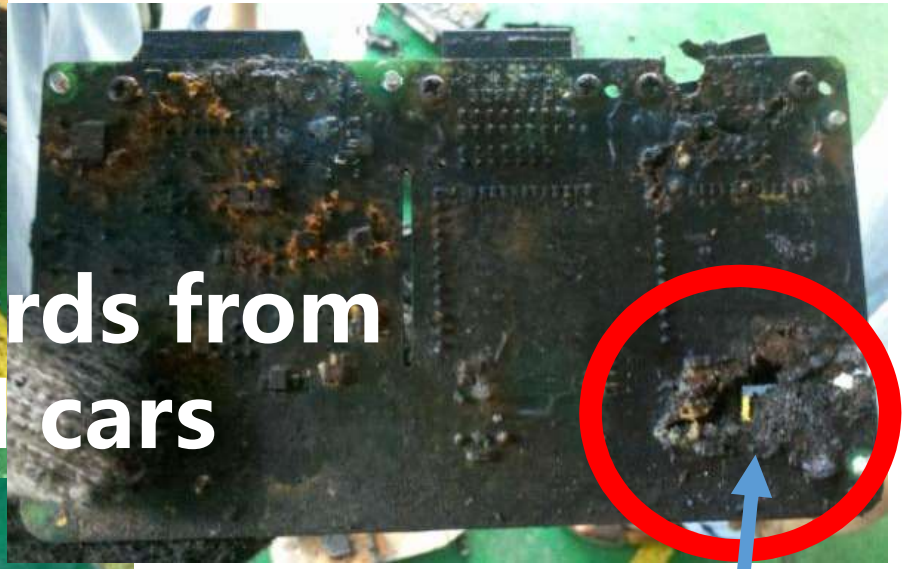
How can water leak into the battery pack, yet gas cannot escape?



- Water with dust leaks into the case through small gaps, which are mostly on the case bottom, (we found solids also produced during water soaking)
- After a few hours, the dust settles down and plugs the gaps
- Gasses are trapped above the water level and can’t leak out from the gaps

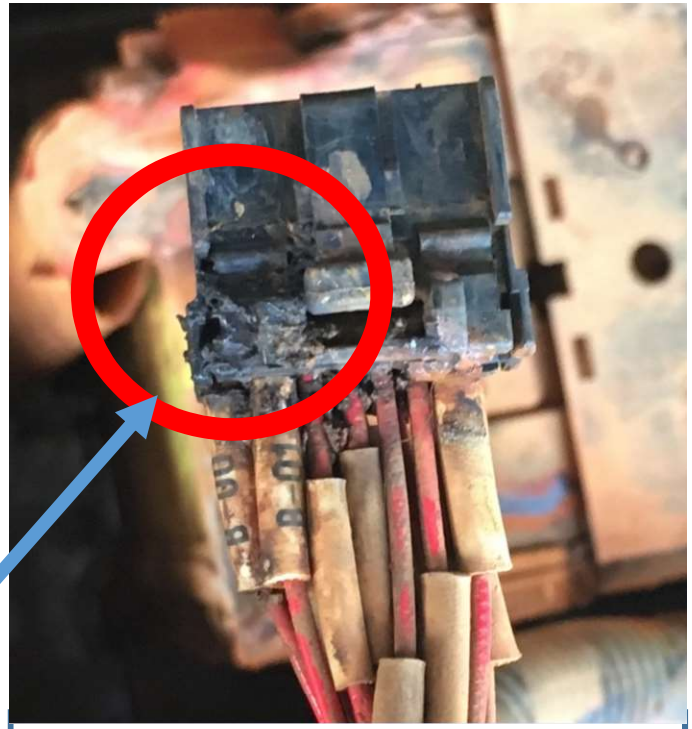
Characteristic 3---Burn Marks on PC Boards

PC boards from burned cars



Burned Holes

Burned adapters



Evidence shows when water leaks into battery case, electronic circuitry burns possibly because of unusual current flow

PC boards from cars not burned but had water leaked into battery case

Characteristics of fire after water immersion

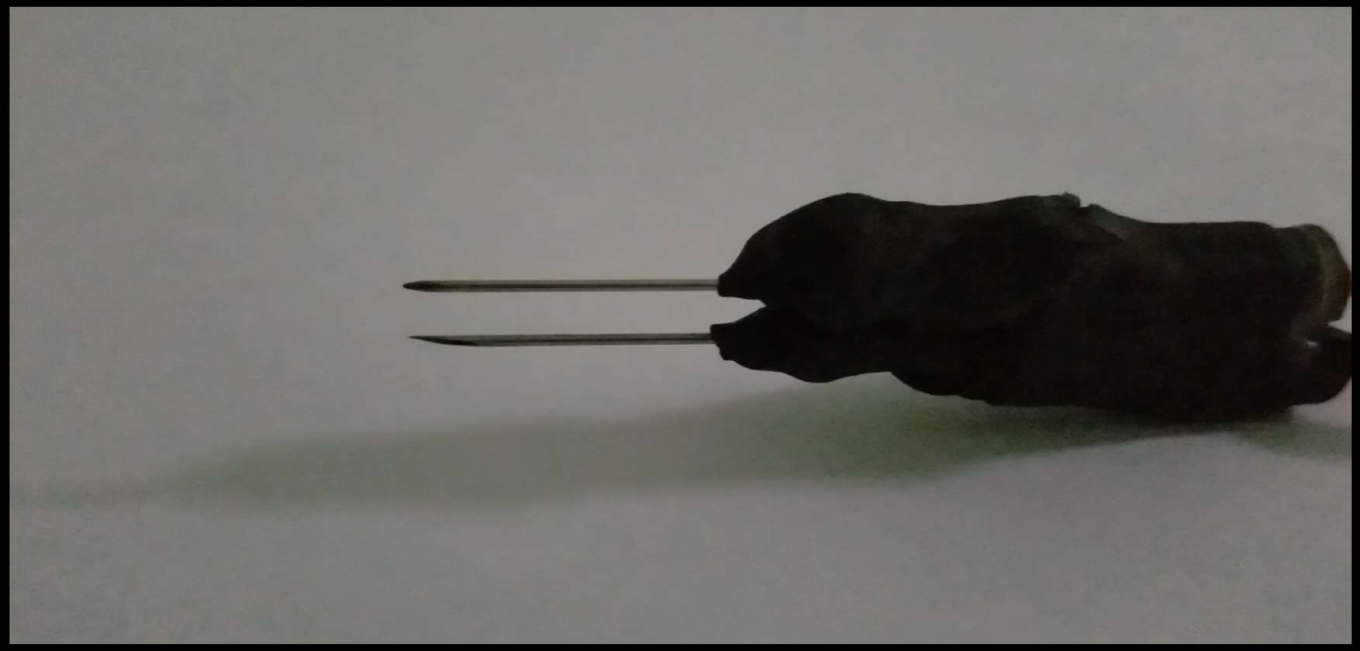
- Time delay before ignition
- Gas Production
- Burn Marks found on PCB

Confirmation Tests of Gassing

0.28KWh battery module soaked in clear water

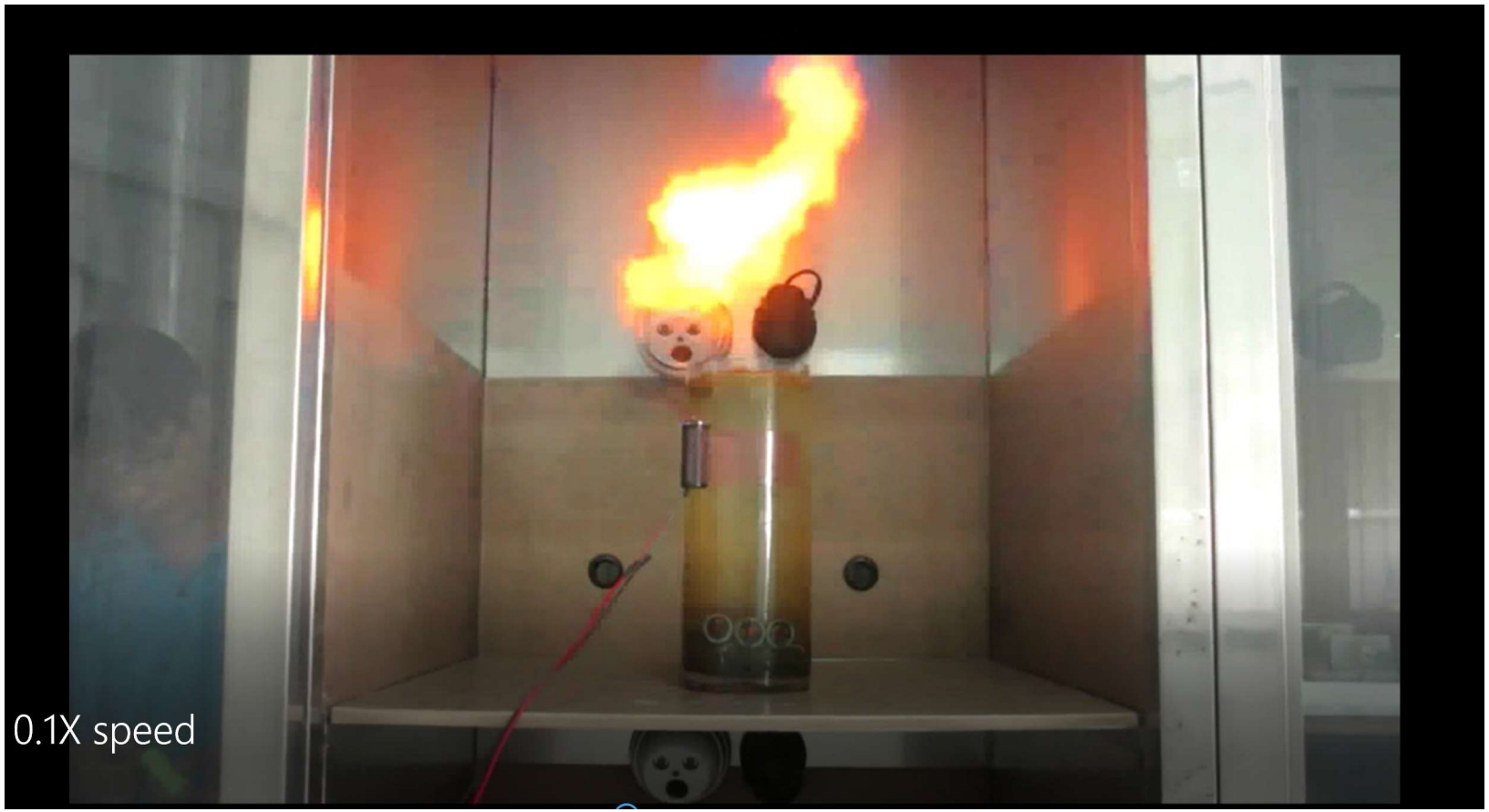
After 48hours

Video of Ignition device



Video Confirmation test of gas burning

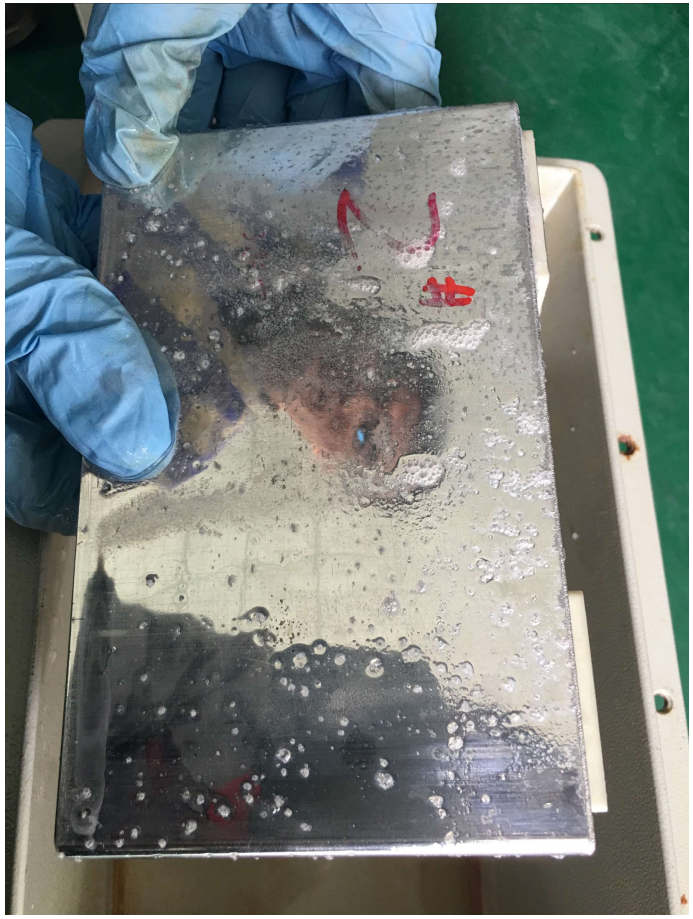
Evidence of flammable gasses produced during water immersion



Power Batteries in Al cans Soaked in Water

24h 之后

Power batteries in Al cans soaking in water



Gas Production Reactions for Cells in Steel and Al Cans

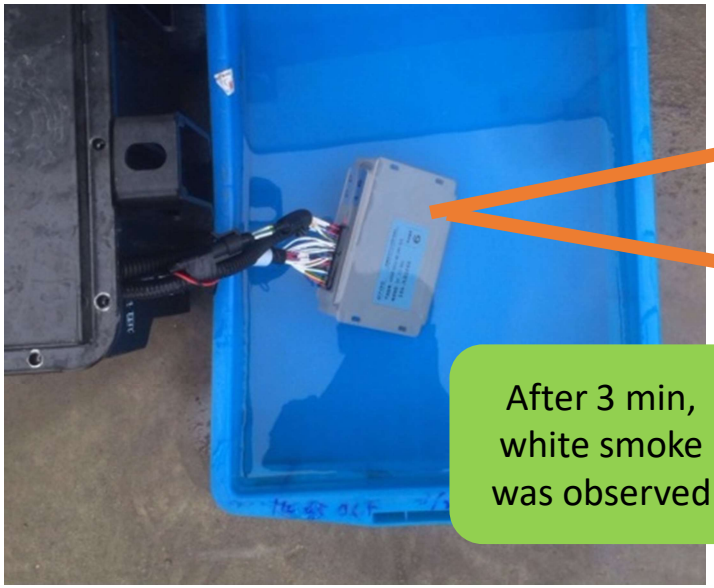
	Positive electrode	Negative electrode
Steel can	$4OH^- \rightarrow 2H_2O + O_2 \uparrow + 4e^-$ $Fe + 3OH^- \rightarrow Fe(OH)_3 + 3e^-$	$2H_2O + 2e^- \rightarrow H_2 \uparrow + 2OH^-$
Al can	$4OH^- \rightarrow 2H_2O + O_2 \uparrow + 4e^-$ $Al + 3OH^- \rightarrow Al(OH)_3 + 3e^-$ $2Al + 2NaOH + 2H_2O \rightarrow 2NaAlO_2 + 3H_2 \uparrow$	$2H_2O + 2e^- \rightarrow H_2 \uparrow + 2OH^-$

Oxygen and Hydrogen are produced in both reactions, and at the ratio needed for explosion

Identifying the Ignition Source

IBMS board in water

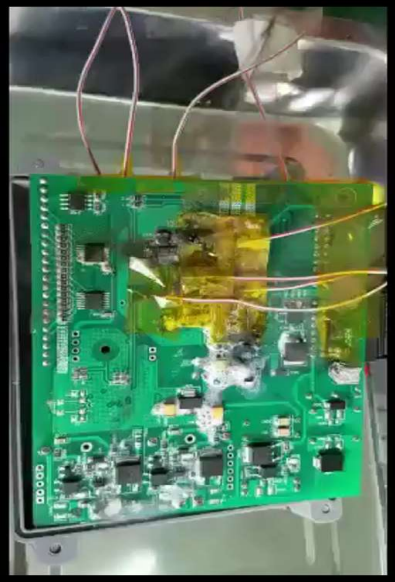
A 16S/12p BMS board soaked in water



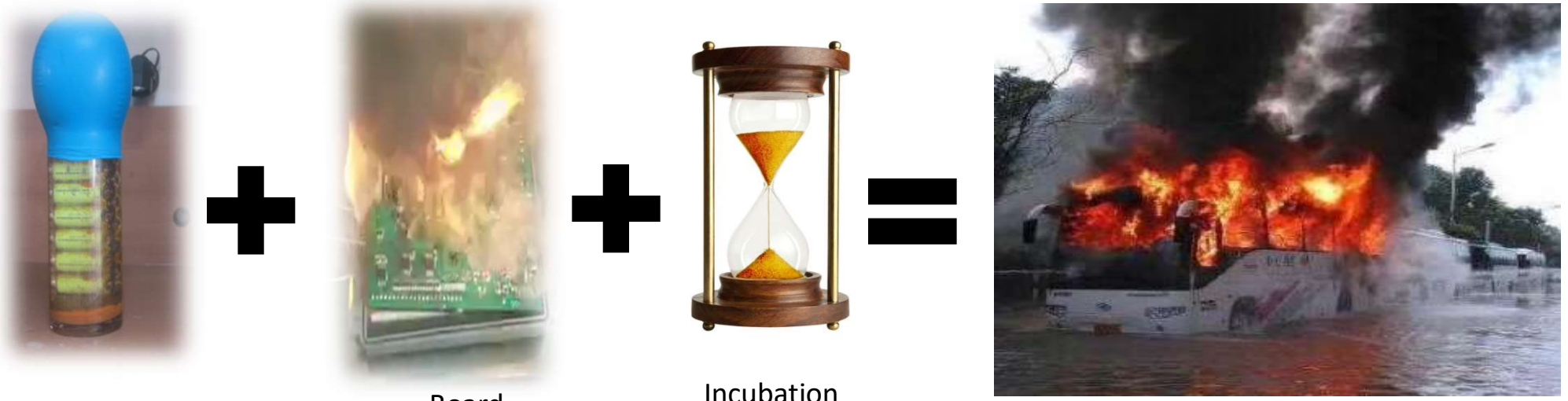
After 3 min, white smoke was observed

After 30 min, the case temperature reached 68°C,

Videos of BMS board caught fire in water



A synergistic mechanism of fire for EV's in water



Gassing

Board sparks

Incubation Time

Vehicle Fire

When water gets into a battery pack, Hydrogen and Oxygen are produced in the concentration and ratio needed for fire. Under certain circumstances, the circuitry in the BMS can spark to ignite the flammable gas mixture, resulting in vehicle fire.

Recommendations for Improved Safety：

- EV power battery packs have to be airtightly made to prevent water leaking into the housing.
- The BMS needs to be able to detect water leakage into the pack in order to avoid disastrous fire or explosion
- Never trust a water leaked pack even the EV is driveable as the incubation time for initiation of fire can’t be known

Thank you for your attention！

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