



NHTSA

NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

Li-Ion Battery Pack Immersion Exploratory Investigation

UN GTR No. 20 – EVS 25th IWG

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Li-Ion Battery Pack Immersion Exploratory Investigation

Immersion of an electrified vehicle's battery pack is a relatively infrequent occurrence in the real world

Seven batteries were tested for immersion as well as post-immersion smoking or fire.

[Report published August 2021](#)

[Previous testing published in 2019](#)



Existing Immersion Standards

- SAE J2464 NOV2009 – 4.3.5 Immersion Test (Module or Pack Level)
 - “With the DUT in its normal operating orientation and at full state of charge, immerse the DUT in ambient temperature salt water (5% by weight NaCl in H₂O) for a minimum of 2 hours or until any visible reactions have stopped” (SAE International, n.d.)
- USABC Battery Abuse Testing – 4.4 Water Immersion
 - “Salt water should be an approximation of seawater (3.5% (600 mM, 35 ppt) sodium chloride).... The DUT should remain immersed for (1) a minimum of 2 hours or (2) until failure of the DUT (HSL ≥ 5).... DUT should be monitored for at least 30 minutes after the completion of the test.” (Orendorff et al., 2017)
- ISO 6469-1:2019 – 6.4.2 Immersion into Water
 - “Immerse the DUT in ambient temperature salt water (3.5-5% by weight) for 2 hours” + 2 hours post-immersion observation time. Requirements: No fire, no explosion.” (International Organization for Standardization, 2019)

Test Program

Test Asset #	Battery Type	Capacity	Key Test Parameters
1	PHEV	8.8 kW-hr	Frequent immersion and observation intervals every 15 minutes
2	BEV	16 kW-hr	30-minute immersion time and 1 hour observation time
3	BEV	30.5 kW-hr	Immersion and observation intervals every 15 minutes for 45 minutes.
4	BEV	32.9 kW-hr	2-hour immersion and 2-hour observation
5	BEV	60 kW-hr	1-hour immersion time + 2-hour observation
6	BEV	60 kW-hr	1-hour immersion time + 2-hour observation. 0.1 percent Salinity
7	PHEV	8.9 kW-hr	Short duration initial immersion of 20 minutes prior to first observation period. 0.1 percent Salinity

Batteries were immersed near 100% capacity or the expected maximum charge level achieved during normal vehicle charging.

Samples were selected from a range of manufacturers

5 batteries immersed with 3.5% salinity; 2 tests used reduced salinity to resemble coolant fluid

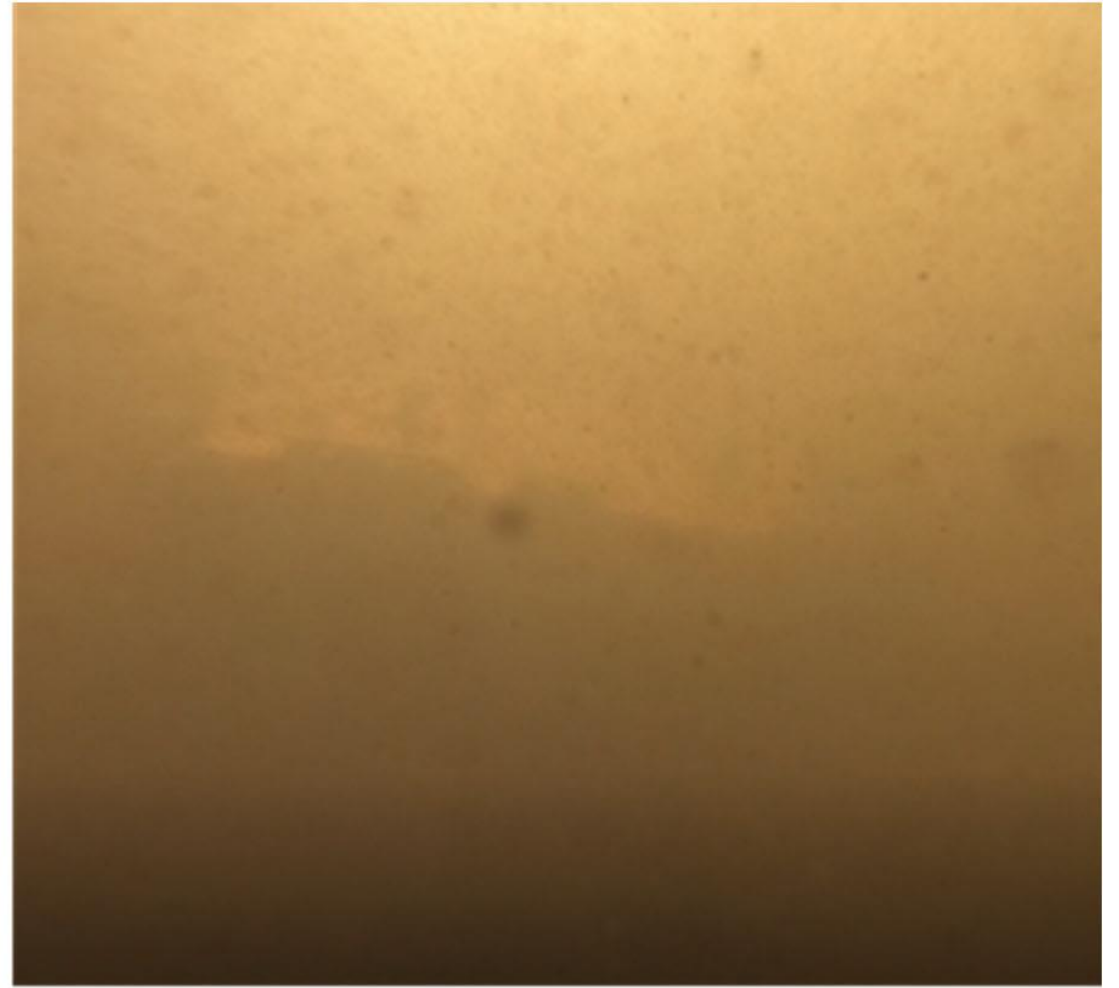
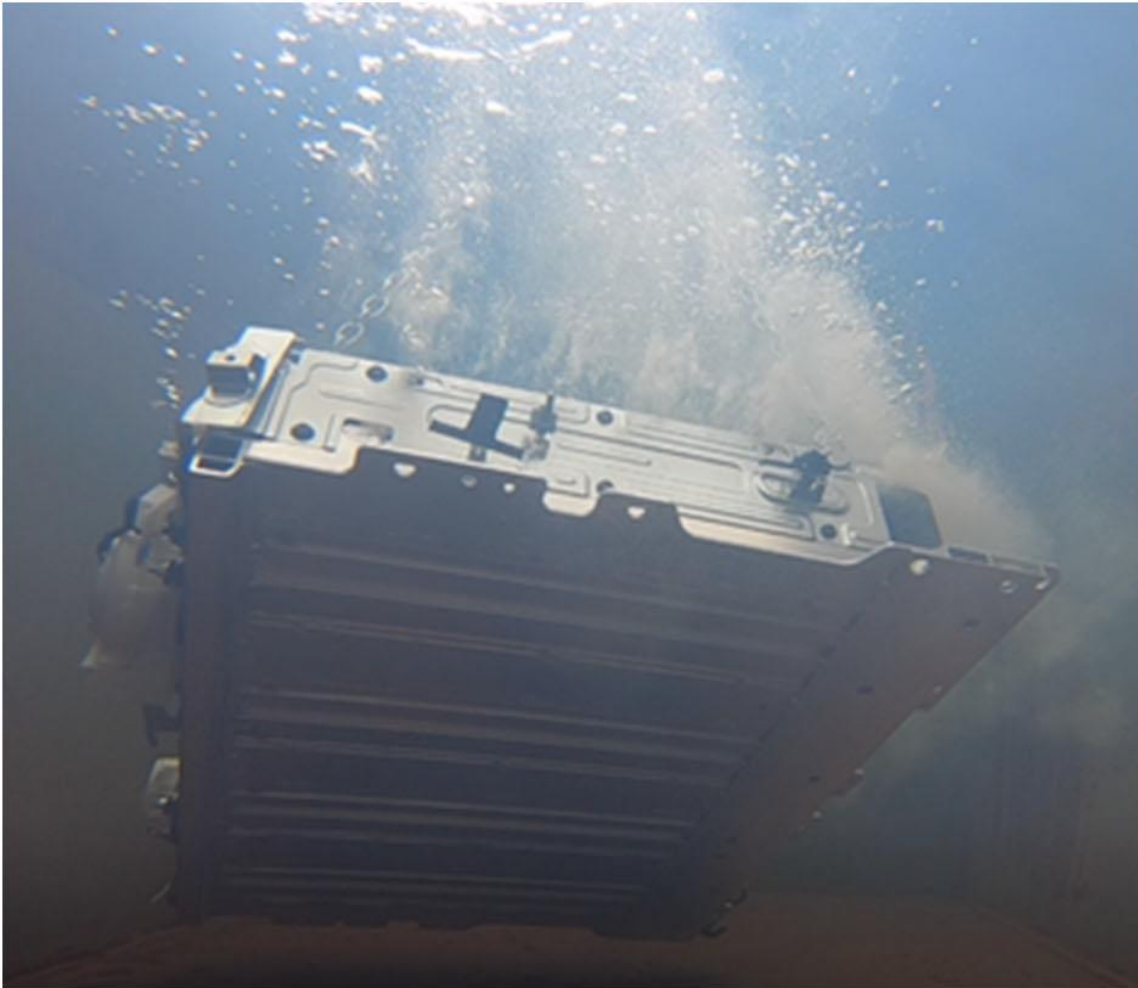
Test Setup



Battery Immersion



Immediately After Immersion & 10 minutes later



Observations

- All the batteries degraded with no adverse reaction while immersed
- 2 batteries had smoke/venting issues post-immersion:
 - 1st Battery was immersed for 20 minutes in water (3.5% salinity)
 - 2nd Battery was immersed for 15 minutes in water (0.1% salinity)
- Primary reactions during immersion appeared to last between roughly 30 minutes and 1 hour. Larger capacity batteries took longer.
- Post immersion batteries were under 50V
- Battery degradation/discharge occurred quicker in 3.5% salinity water.

Based off the research completed to date, a battery immersion test in water of lower salinity (<0.1% NaCl) and shorter immersion duration (<30 min) would be more stringent than a test with longer immersion duration (2 hours) in sea water (3.5% salinity).

Key Take-Aways

- Based on the previous exploratory investigation, longer duration periods may not be the answer, and lower salinity levels need to be investigated further.
- Hurricane Ian – field data monitoring continues.
 - 17 confirmed EV fires in Florida:
 - 15 were Tesla vehicle fires
 - 5 were in open air or on a tow truck
 - 2 were inside residential garages where the homes were lost from the fire
 - 1 Porsche vehicle fire
 - 1 Lucid vehicle fire
 - 3 other structure fires possibly caused by vehicle fires
 - First known EV fire (Tesla vehicle) was on 9/28/22 on Marco Island
 - Most recent EV fire was a Tesla inside a residential building on 10/11/22
 - Fire resulted in minimal damage to the building, but the vehicle fire rekindled hours later when the vehicle was outside the building.