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Vehicle Level Thermal Runaway Test: Parked Conditions

Dean D. MacNeil
Research Officer
Energy, Mining and Environment – Ottawa
613-990-1769

Co-authors :
NRC : Steven Recoskie, Joel Perron, Sébastien Touchette, Brody McLeod
Transport Canada : Kyle Hendershot

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Introduction

Previous work by Canada on thermal runaway testing at the vehicle level was focussed on an active vehicle mode (vehicle on and drive engaged). The objective was to demonstrate that the rapid heating test methodology for thermal runaway initiation was feasible under an active vehicle mode, without inducing any vehicle errors or operational issues for the vehicle.

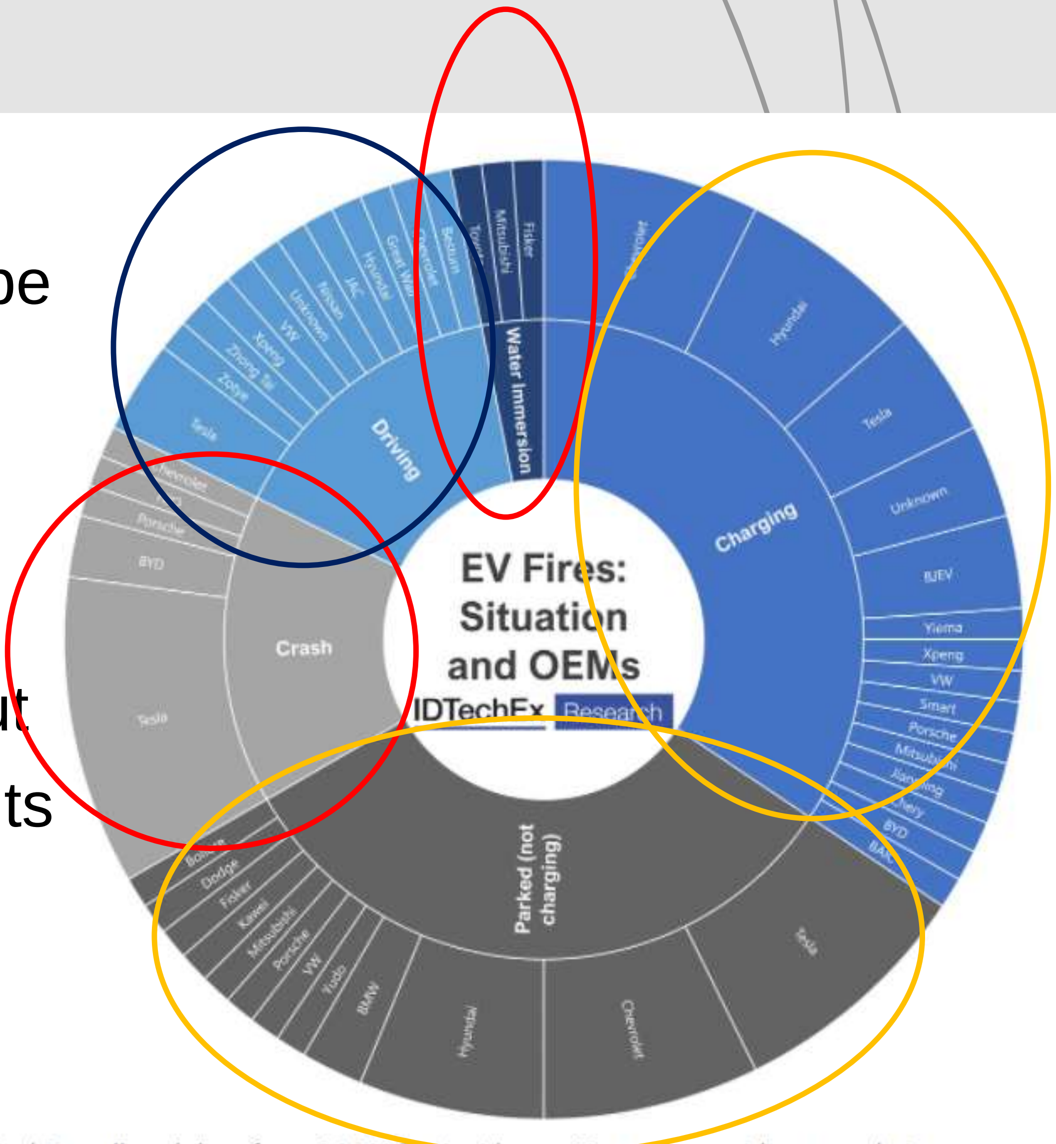
We feel strongly that this is paramount to validating ANY proposed thermal runaway test methodology.

Operational Mode Review

Numerous CPs have provided summaries for EV fires in their jurisdictions. Numerous causes can be identified and some remain unknown.

Other commercial reports show similar trends[1]. Fortunately, some potential fire scenarios are covered within GTR tests methods, others not, but it is clear that a large number of these fire incidents occur within a non-driving mode.

During TF meeting, all CPs agreed a PARKING mode for TR should be addressed within GTR



1. IDTechEx collated data from 96 EV fire incidents. Many occur without an obvious cause. Source: IDTechEx Research

Parking Mode Test Criteria

During Parking, what are the important criteria to evaluate?

Is it occupant safety? Many times no occupants present

Is it bystanders? Many times people are in close proximity

Is it surrounding infrastructure? A battery thermal event may engulf surrounding environment making a small event into a more serious event

From: Hyundai Kona Electric Explodes, Blows Hole In Garage; Cause Unknown (insideevs.com)

Please recall - How is this different from existing ICE vehicle technology where you have a storage container containing multiple liters of flammable solvent. How many ICE vehicles catch fire when parked?

Parking Mode Test Validation - Test Setup

2020 Chevrolet Bolt – Previously used in a rear-end crash test at Transport Canada facility, no damage to battery pack, battery pack enclosure or pack containment ability. Vehicle could be turned on (accessories mode), but contactors to HV pack would not close and no active drive mode could be engaged. Battery coolant lines were full, but pump activities unknown.

DUT was in accessories mode and tested in outdoor environment

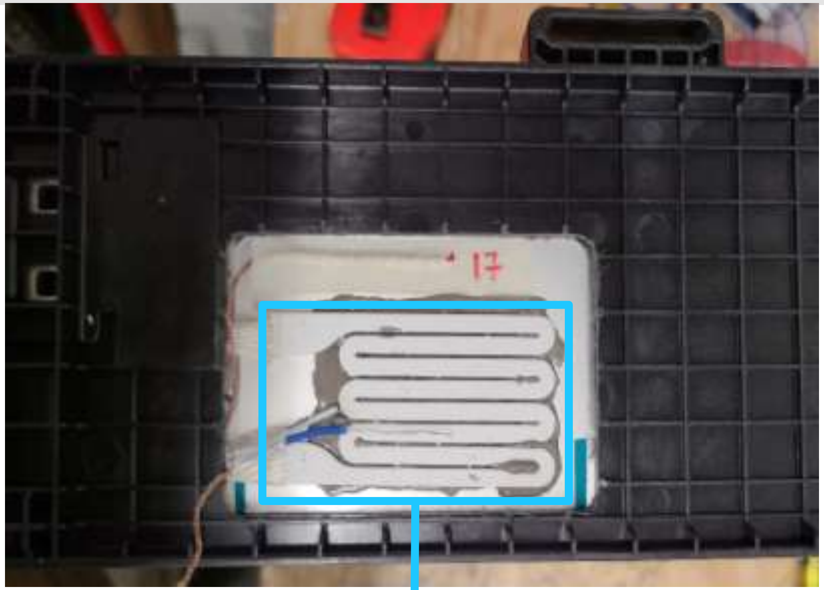
Wheels and Tires removed, vehicle mounted on cinder blocks at jack points

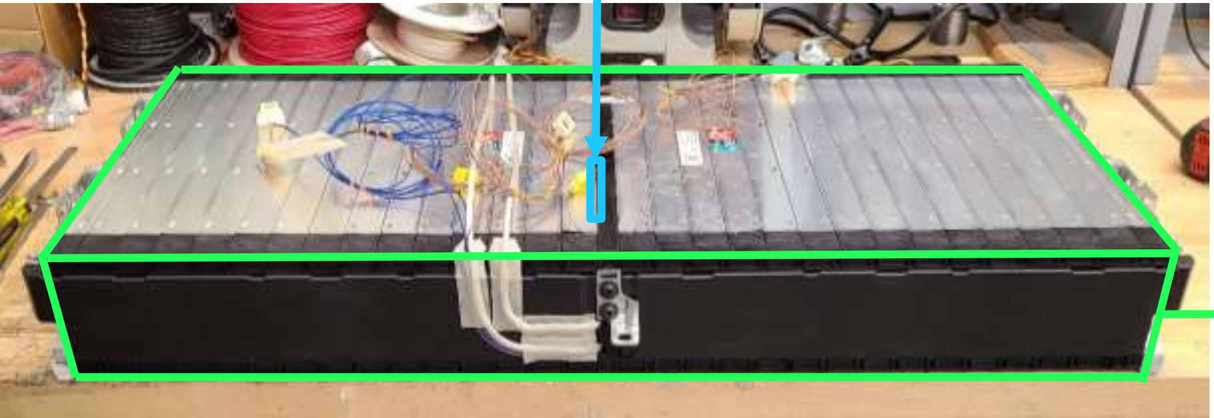
Ambient Temperature 16°C, Average Battery Pack Temperature 26°C

Wind 5 m/s (18 km/h) from the North, test performed at YOW airport

Instrumentation

- 45 temperatures (35 internal pack, 5 in vehicle, 4 in tent, 1 outdoor ambient)
- 10 module voltages
- Boroscope camera, 4 video cameras, 1 IR camera
- Multi-gas meter (CO, H2S, O2, CH4/LEL), FTIR
- CANBus
- Pressure inside tent





Primary heater location

Module Install

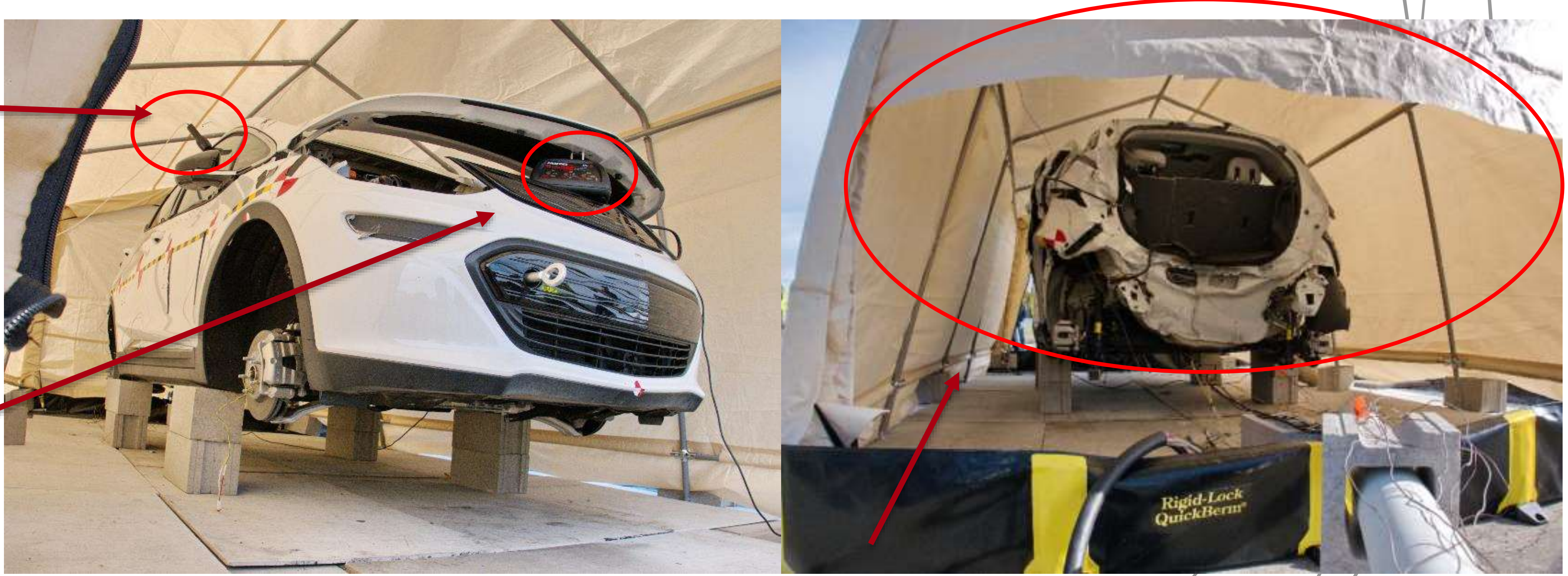
Secondary heater location

Parking Mode Test Setup - 3

To investigate a garage scenario, a fabric tent shelter was installed around the DUT.

Multi gas analyzer

12V charger removed, hood closed prior to test



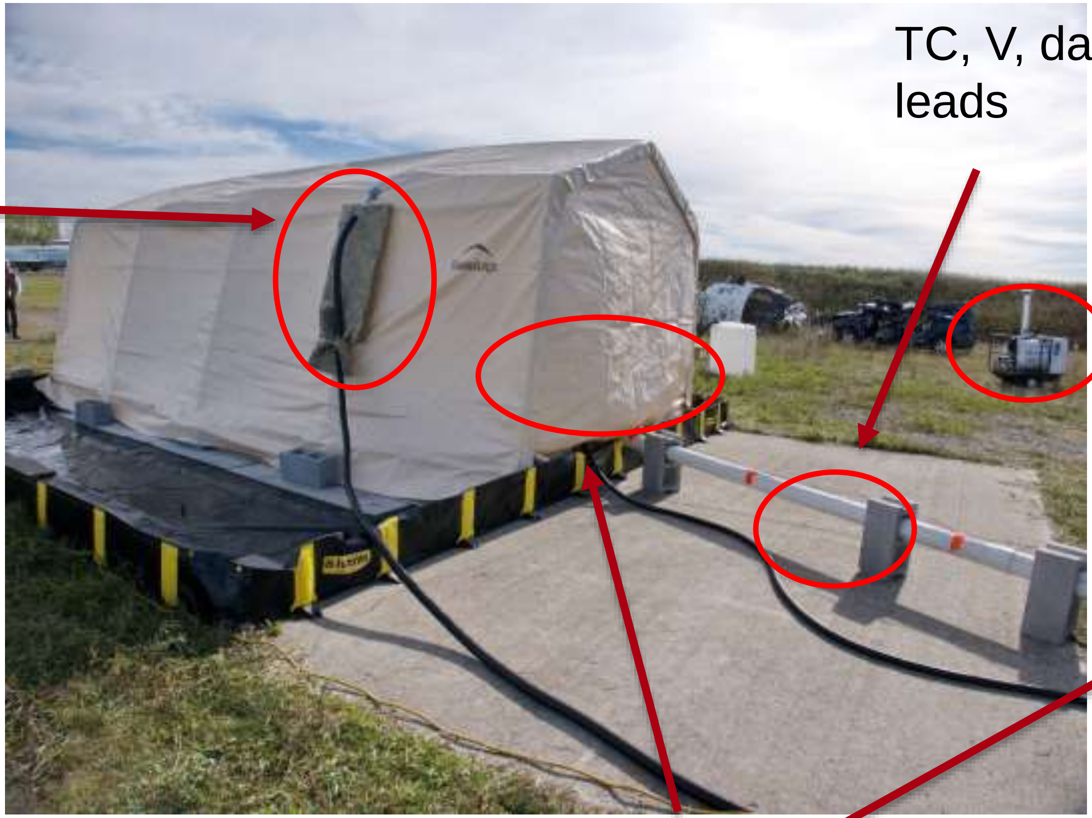
Shelter had opening at front and back to permit some airflow in/out of the shelter

Parking Mode Test Setup - 4

Heater for maintaining battery temperature overnight

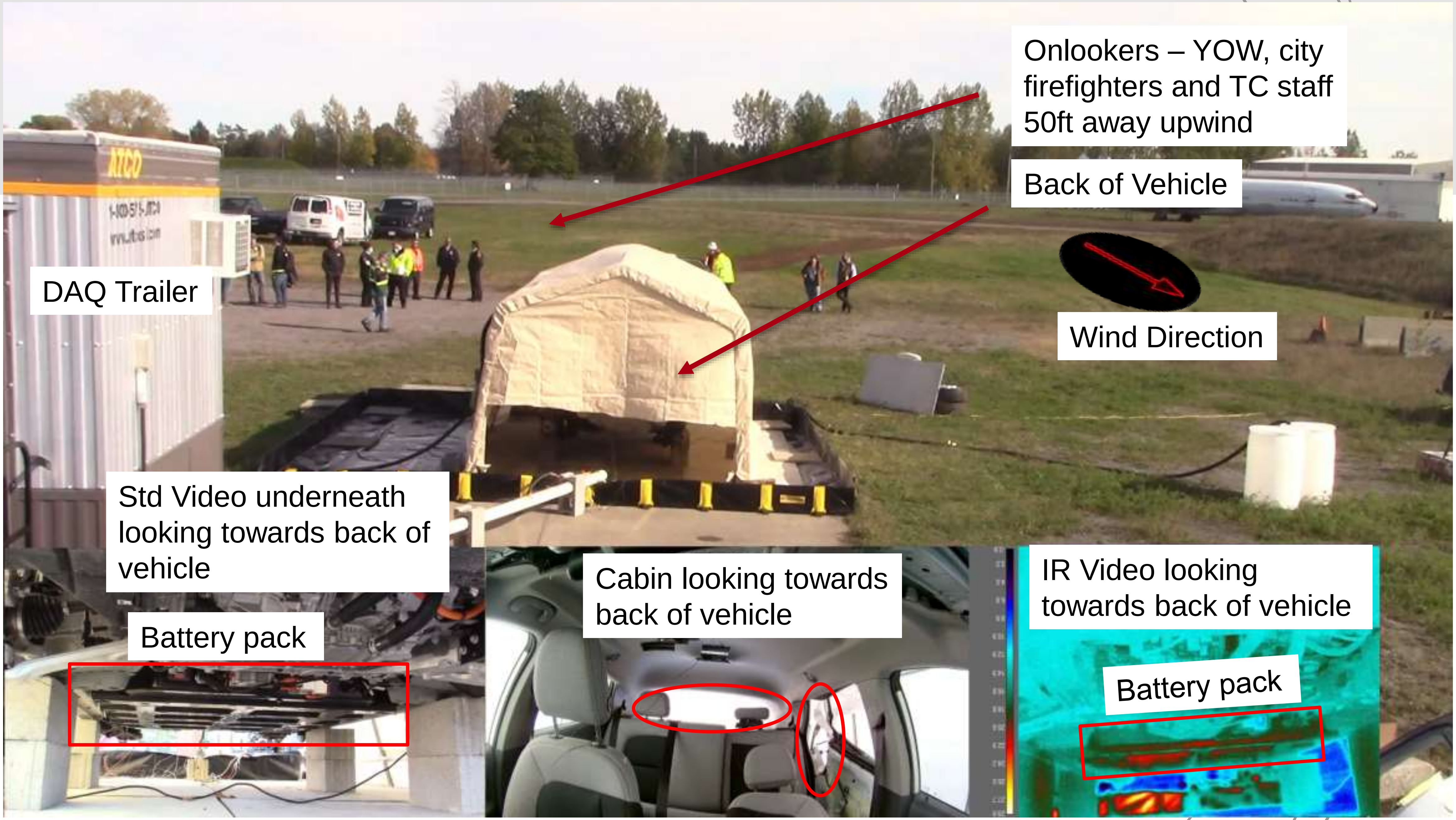
TC, V, data leads

Collection of gas at top of shelter for FTIR gas analysis



Opening created in shelter (front and back) prior to test to permit gas flow

YOW Fire trucks on standby


Onlookers – YOW, city firefighters and TC staff 50ft away upwind
Back of Vehicle
Wind Direction
DAQ Trailer
Std Video underneath looking towards back of vehicle
Battery pack
Cabin looking towards back of vehicle
IR Video looking towards back of vehicle
Battery pack

Event Log

00:00 Video and Heating Starts

00:25 First audible Thermal Runaway with visible white smoke released

00:37 Smoke visible in cabin**

01:06 + release of pressure/gas in waves; visible in IR camera and sound

01:58 FTIR gas analysis reveals increase in several gas emissions (spikes)

03:07 White smoke begins to intensify

04:30 Significant heat release from pack visible in IR camera (potential rupture?), smoke begins to darken and intensify further, FTIR is oversaturated and is shut down

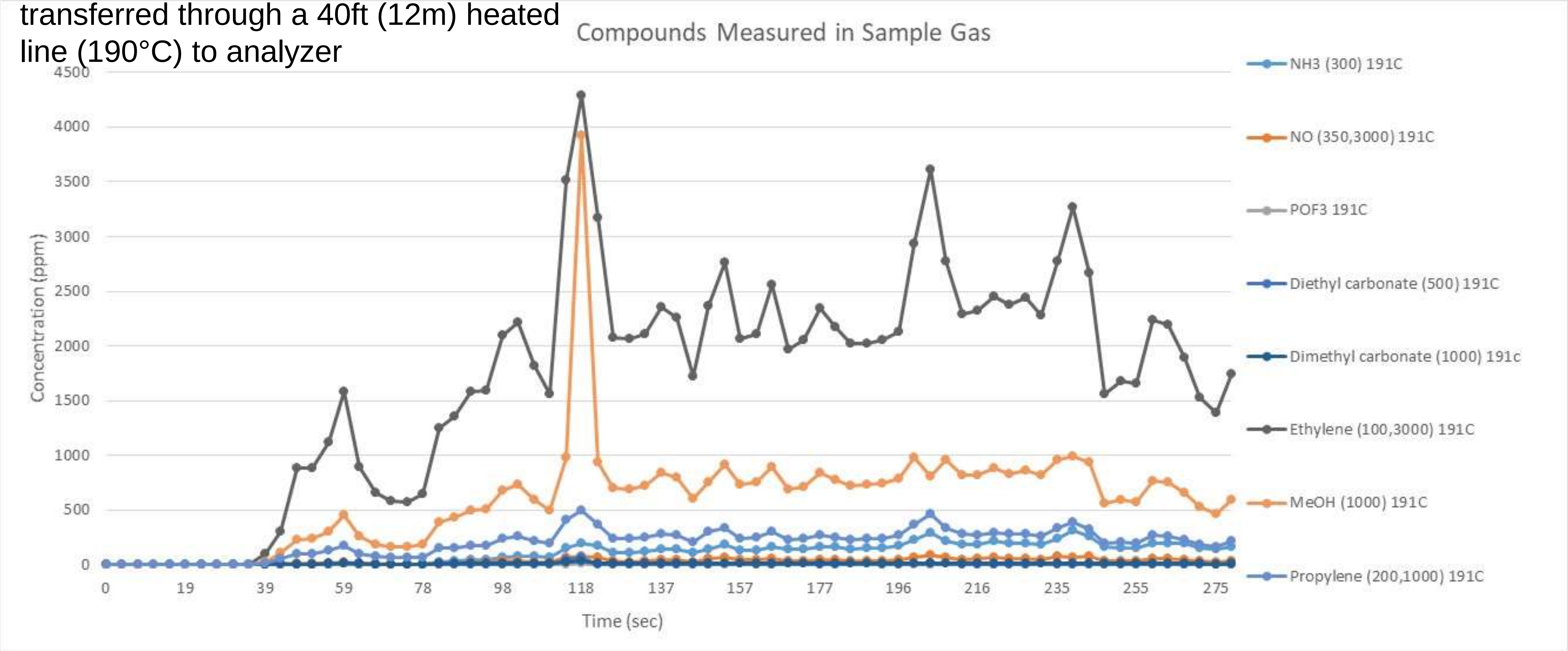
05:45 FTIR sampling line removed, smoke darkened with intense release from tent

08:49 deflagration, tent consumed, first visible flame

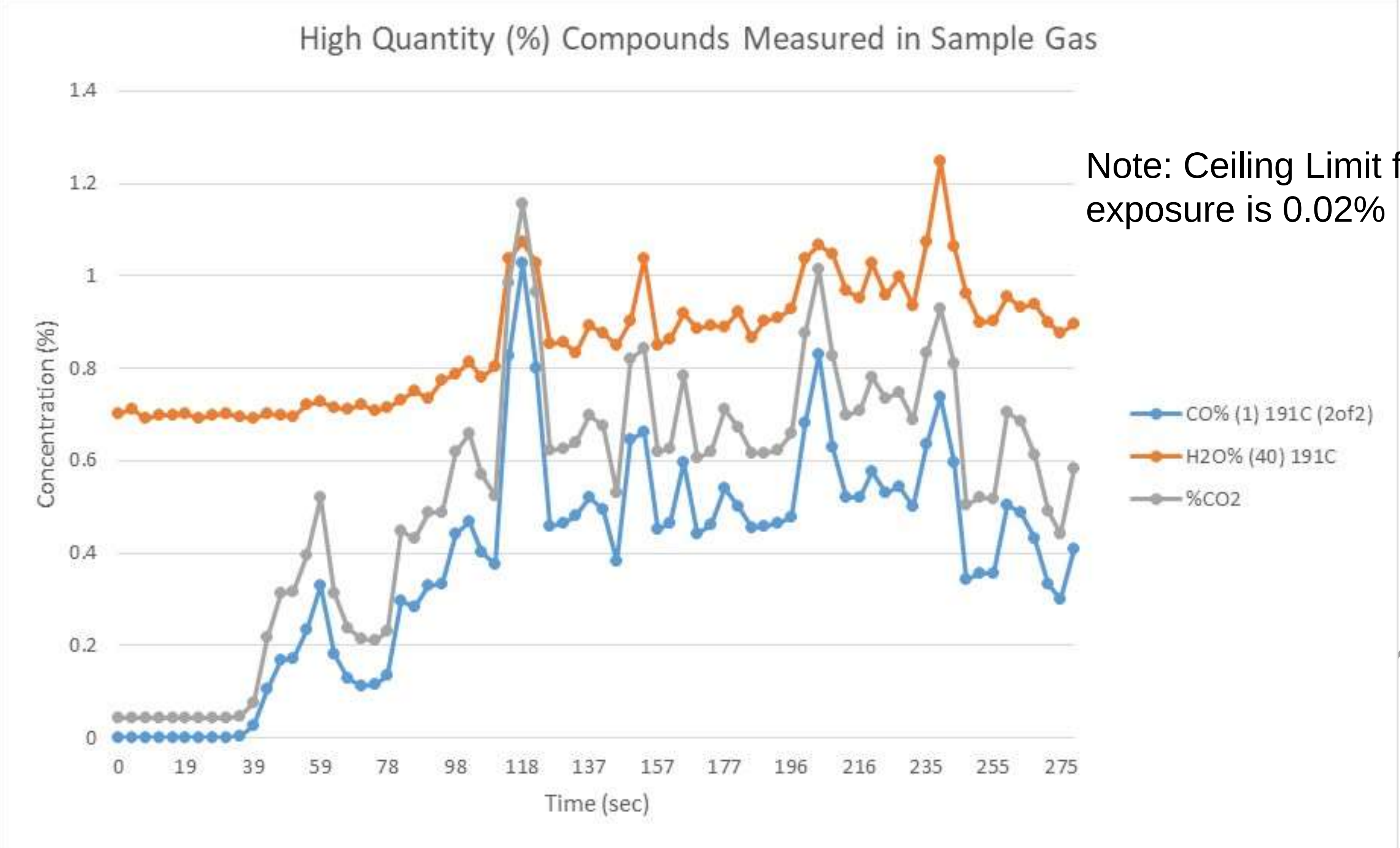
12:22 Water applied

Test Results - Gas Analysis

NOTE: Gas collected at top of shelter and transferred through a 40ft (12m) heated line (190°C) to analyzer



Test Results - Gas Analysis



Note: Ceiling Limit for CO exposure is 0.02%

Test #2 – vehicle #2 (similar condition as #1)

Test was repeated from the “secondary heater” site (on slide 6) – Initial TR initiation and observations were identical, but due to differing wind directions (head on), gas accumulation inside tent was less, oxygen availability was larger and a smaller deflagration event occurred, with visible flames at 7:00 min causing tent to melt.

Observations and Lesson Learned

Visible gas emissions can be a significant danger during a single cell thermal runaway test at a vehicle level. Testing within an enclosed space can concentrate these emissions and lead to an deflagration event in <10 min of first TR event. This highlights the dangers to potential occupants, bystanders and infrastructure.

Flames require significant “free” and accessible oxygen to develop and should not be the only evaluation criteria for thermal runaway testing as there is significant heat/gas evolved without visible flames.

Test conditions for an exterior performed test need to be considered closely in order to ensure repeatability and meaningful comparisons.

Open Questions

1. What is the important test criteria for a parked scenario? Is gas emissions a significant concern? If so, how to quantify it? Does gas release pose a concern to occupants, by-standers or infrastructure and is this a variable that is in the scope of the GTR?

2. Would occupant e-gress time be affected by release of significant smoke? How to validate smoke relative to e-gress time? How does a component level test account for enclosed structures?

3. Should ALL battery pack/vehicle designs be capable of addressing a SCTR passively (parked scenario)?

4. Is visible fire a key metric for SCTR testing at system level?

Conclusion

Two separate single cell thermal runaway tests were conducted on parked vehicles within an enclosed structure.

Dashboard warnings are not visible from outside the vehicle.

After ~9 min of smoke release, a deflagration followed by a significant vehicle fire occurred. The fire engulfed the complete vehicle immediately and consumed the tent structure.

Significant amount of water was required to extinguish the vehicle fire.

Thank you for your kind attention!

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