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# Rapid Heating Test Methodology : Vehicle (using cylindrical cells) Test

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# Review of Previous Canadian Vehicle Level Thermal Runaway Tests

1. **EVS18-E1TP-0500** – June 2019

Setup : PHEV with pouch cells and liquid cooling, active drive mode.

Result : “reactive cooling system”, HV contactors opened (and drive disabled) within 30 sec. of TR, service HV on vehicle display, TR propagation to 10 cells.

2. **EVS20-E1TP-0400** – January 2021

Setup : EV with pouch cells and passive cooling, active drive mode.

Result : several warnings on vehicle display, HV contactors open (and drive disabled) within 7 sec of TR event, significant gas evolution over time but cabin remained tenable until 13 min after TR, external fire 12 min after TR event, TR propagation to the half the pack over ~20 min.

# Review of Previous Canadian Vehicle Level Thermal Runaway Tests

3. **EVS23-E1TP-0400** – March 2022

Setup : Two EVs with pouch cells and liquid cooling, HV contactors open (from a previous CMVSS 305 rear impact test), fabric tent (simulated garage) around vehicle and vehicle placed in “accessories” mode.

Result : TR initiated in 25 sec, significant smoke emitted with deflagration event at 7 and 9 min after initial TR, significant concentrations of CO inside tent, TR propagation to all cells over ~15 min.

# Vehicle test with cylindrical cell pack architecture

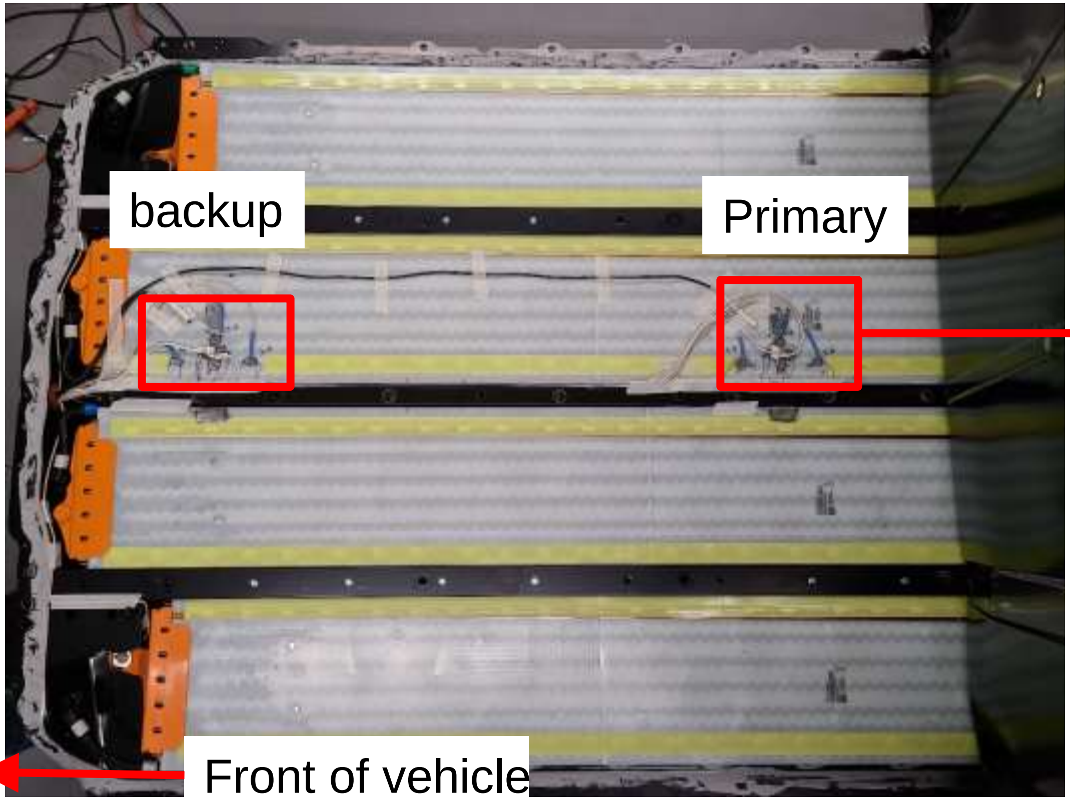
- A vehicle, using cylindrical Li-ion cells, obtained from Transport Canada **AFTER** a CMVSS 305 rear impact test was performed;
- No damage to the battery pack or any of the HV/cooling systems;
- After replacing fuse and bypassing the front motors, the vehicle could be turned on (reduced power mode), driven and charged without any errors relative to the battery or HV systems;
- Coolant system was re-filled, but not the refrigerant;
- Rear doors and rear hatch would not close (continuous power draw on 12V (and thus HV system)).

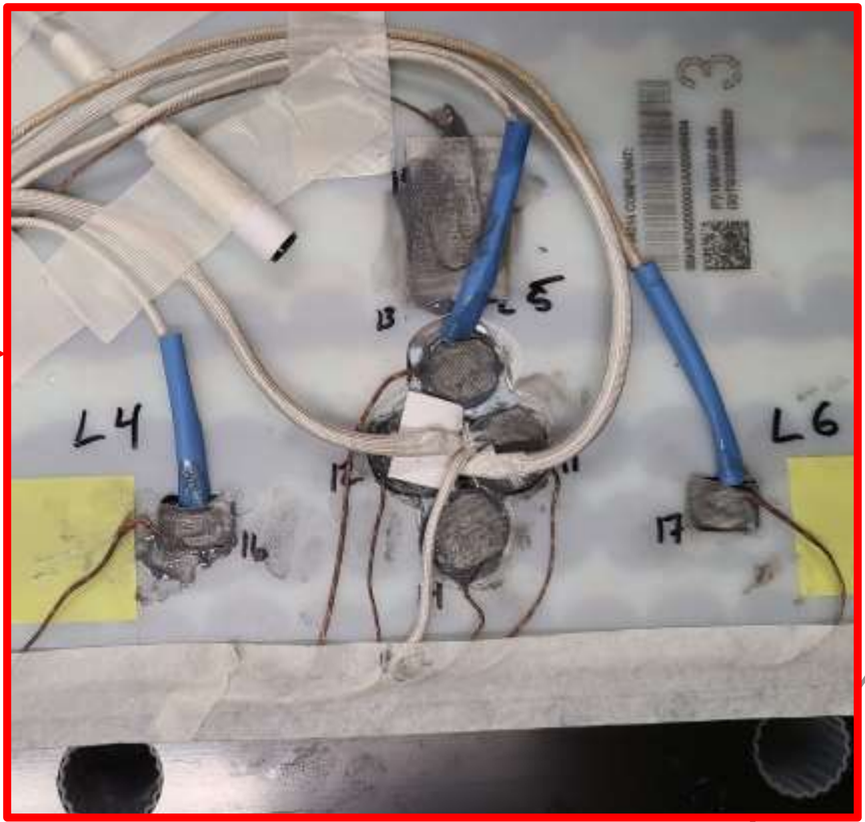
# Pack Instrumentation


9mm x 36mm x 0.7mm

**Extraction / heater install / reseal / reinstallation following OEM service manual;**

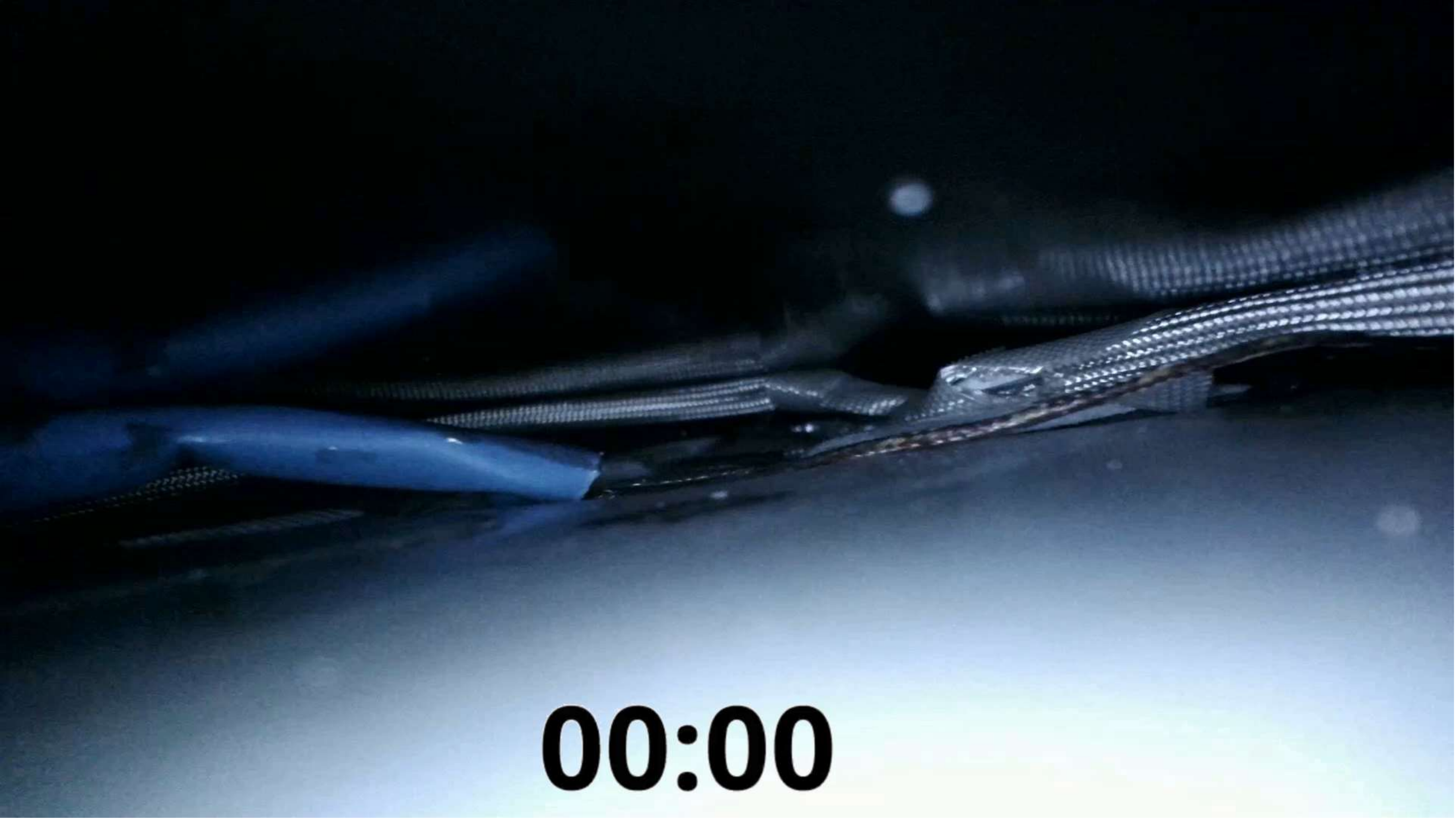
**No battery related error codes present after reinstallation and vehicle could be placed in drive or charge mode (heater is “invisible”).**




# Test Setup

- 35 temperatures (20 internal pack, 11 in/on vehicle, 3 in tent, 1 outdoor ambient)
- 4 module voltages, 4 brick voltages (2 targets, 2 adjacent)
- Pressure inside HV Pack
- 2 boroscope camera, 4 video cameras, 1 IR camera
- FTIR (tent atmosphere)
- 244 signals over CANBus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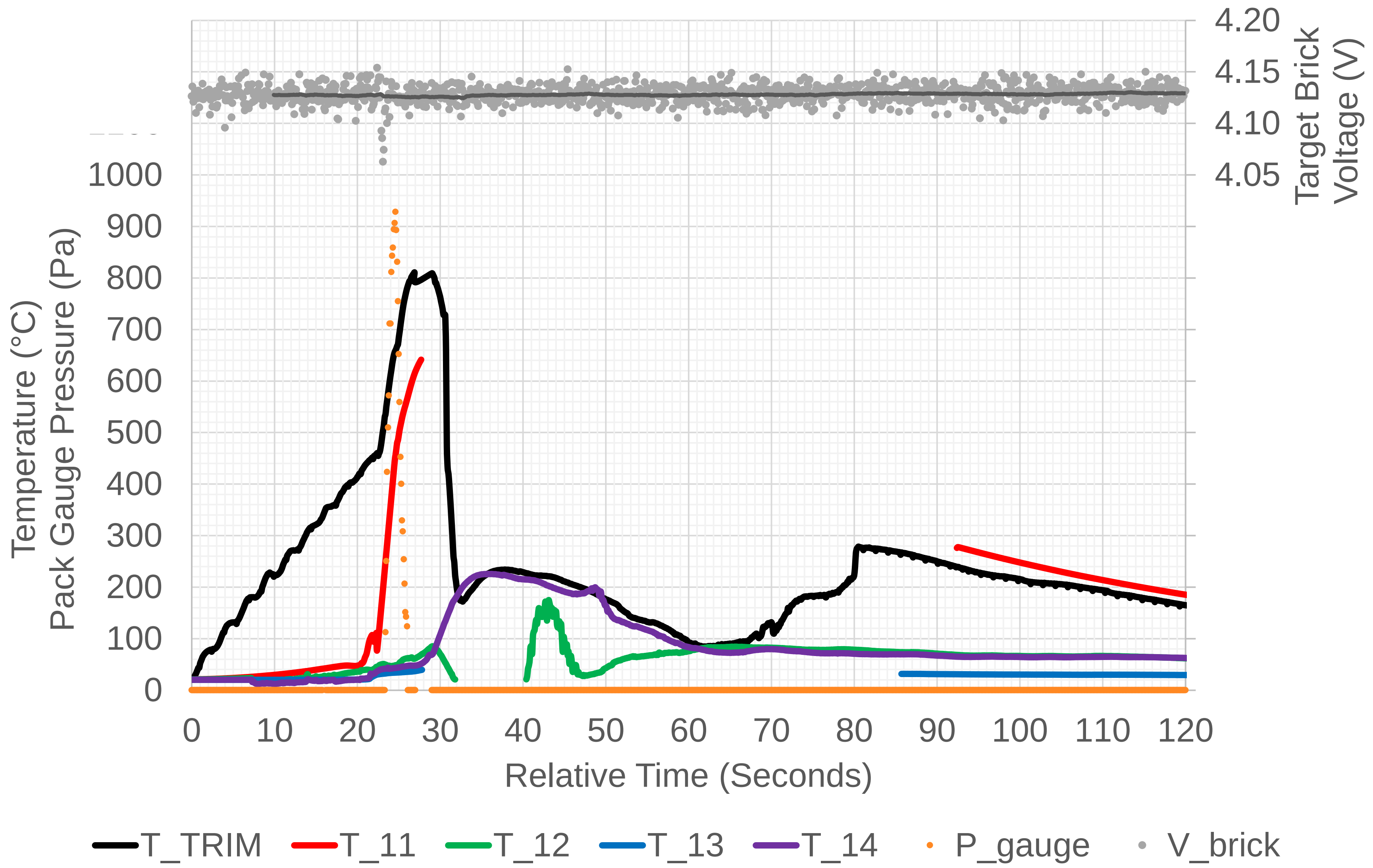
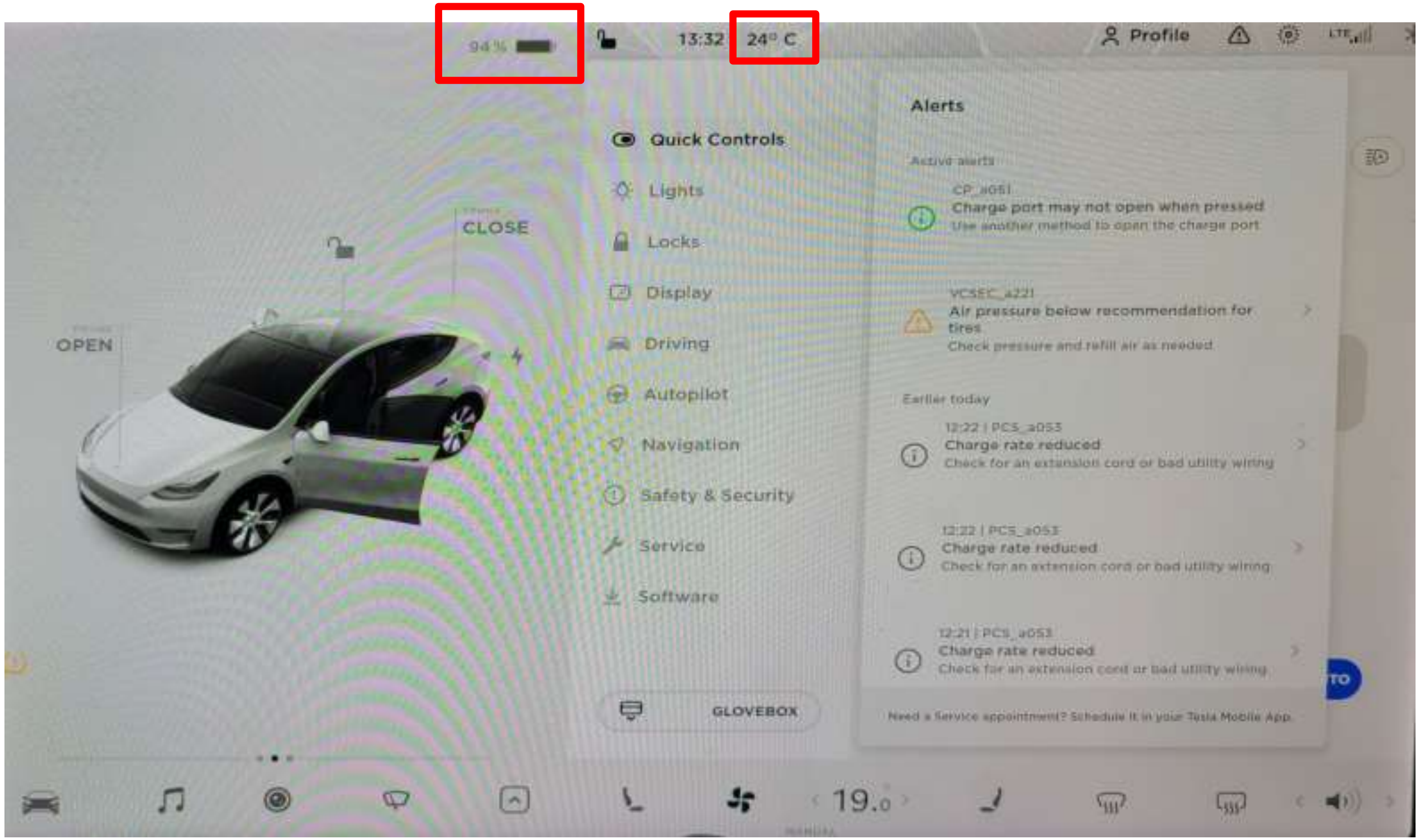
# Temperature/Voltage Data




- Heater set to 20°C/sec to 500°C, TR in 23 sec;
- Electrical disturbances on some temp. signals between 30 and 90 sec;
- Instantaneous voltage drop by 66 mV, detected by high speed data acquisition;
- Peak Pack Pressure measured during SCTR: 930 Pa;
- No change is coolant flow throughout experiment;
- ~3 ppm CO detected, as measured by FTIR, at top of tent roughly 4 min after heating.

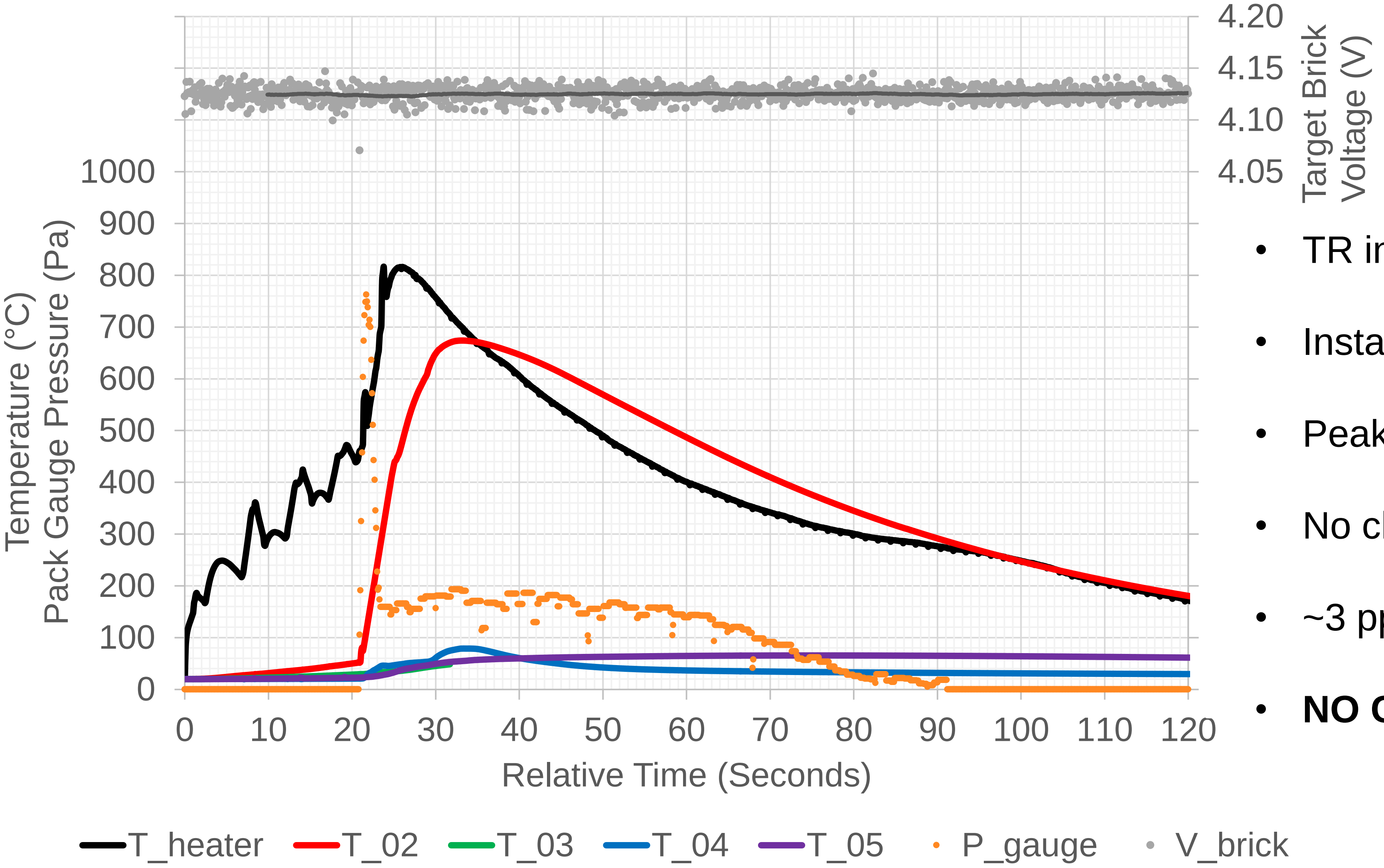
# Dashboard Display (same before and after)




- Charge port door not latching due to rear end crash damage
- Tires were removed
- Charging by generator
- **NO** other active alerts

# Back up Site Activation

After waiting for area around Primary heater to cool down, Backup heater was activated




- TR in 22 sec
- Instantaneous voltage drop = 54 mV
- Peak pack pressure = 760 Pa
- No change in coolant flow
- ~3 ppm CO detected at top of tent
- **NO Change** in the dashboard display

# Detection/Warnings?

Two separate interior single cell thermal runaway tests were conducted within one vehicle, under parked conditions, within an enclosed structure.

There was no noticeable drop in voltage of the module or pack.

There was no indication to the driver that the thermal runaway event occurred, ~3 ppm CO detected in tent <5 min after TR events.

Additional instrumentation, **not native** to the battery pack was used to confirm thermal runaway had occurred (visual, T, P). **In a regulatory test the temperature of the heater would be sufficient to determine thermal runaway had been achieved.**

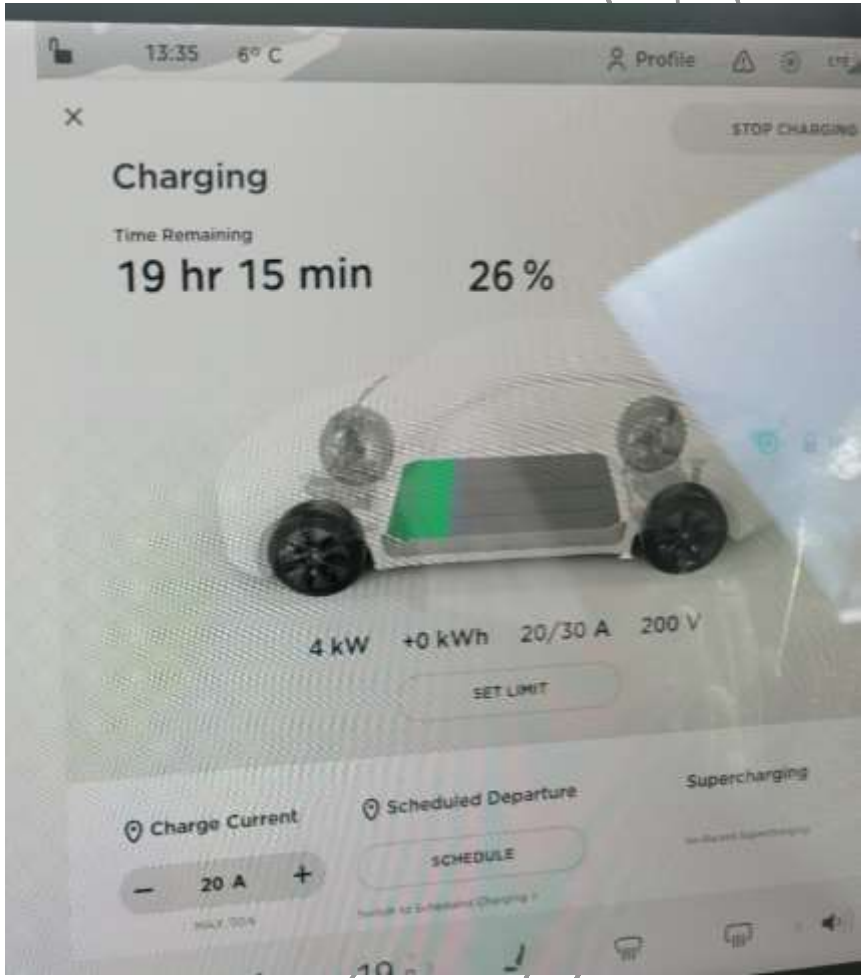
# Additional Information

The next day, the vehicle was **DRIVEN** away from test site (into adjacent field) with no warnings to driver;

**AND** the vehicle accepted a charge with no warnings apparent to occupant.

3 weeks after the test, the vehicle can still be driven and charged (L1 and L2) without warnings.

We will be performing teardown soon.



# Conclusion

The rapid heating test methodology has been successfully applied to a vehicle using a cylindrical cell architecture against **TWO INTERIOR target** cells. With the proper choice of heater, the methodology is very versatile.

Thermal runaway was only detected, in this vehicle, with non-native instrumentation. A boroscope camera is an effective tool, as well as the temperature of the heater and neighboring cells for TR detection. Detecting thermal runaway for packs consisting of many cells in parallel can not be made based **solely** on voltage.

Vehicle could be driven and charged for at least 3 weeks after two sequential single cell thermal runaway events in the battery pack.

# Thank you for your kind attention!

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