Canada and United States of America

Comments for Battery External Fire Safety

As an action item from the 9th EVS IWG meeting, we are submitting the U.S. and Canada's position on fire exposure test. We would like to provide the following recommendations to TF-7 for consideration:

1. **Vehicle level fire test**: Recommend no test.
2. **Pack level short duration fire exposure test**: Recommend removing this requirement from the draft GTR as the exposure time is insufficient to cause an explosion.
3. **Pack level long duration fire exposure test**: Recommend either (1) adopting the External Fire Exposure test of UL 2580 or (2) defer this topic to Phase 2 to allow more time for observation of real world data regarding battery explosions induced by fire.
4. **LPG vs gasoline pool fire**: Recommend using LPG for the fire test. We recommend equivalency to the gasoline pool fire be determined by temperature at battery surface and total heat release.

The following sections provide summaries of Canada's fire tests and details for the rationale and justification for the above recommendations.

Canada's Testing

Vehicle Tests – tested 3 Li-ion EVs and 2 Li-ion PHEVs and 2 ICE vehicles for a period of 30 minutes. No vehicles or battery packs showed catastrophic explosion though there were numerous pops and flares during the test, which includes tires, shocks, and air bags. One of the PHEV also showed a jet of fire because of the gasoline tank getting involved in the fire. The battery pack did not provide additional heat to the test until between 500-900 seconds (8 minutes – 15 minutes) from the start of the test. Batteries with 100% SOC (vehicle readout) were involved in the fire earlier than 85% SOC (vehicle readout) batteries.

Component Tests - The UL 2580 test (minimum 590°C in 5 minutes and a burn duration of 20 minutes) was conducted on two types of lithium-ion battery packs from EVs (A & B). However, the duration had been extended to 30 minutes to ensure full reaction of the battery packs. Tests were done with propane after calibrating flame temperature to be similar to gasoline flame (800°C). Two packs of Battery type A were tested with 100% SOC. Two packs of Battery Type B were tested with one at 100% SOC and the other at 0% SOC. Findings were:

- No explosions were observed in these tests.
- Propane is more controllable test medium than gasoline.

- The tests with battery A showed good repeatability with propane gas fuel.
- The tests with battery B showed that a battery with 100% SOC was involved in the fire earlier than that with a 0% SOC and had a higher peak heat release rate. (but the total heat release of both packs was about the same when burned to completion)
- Battery packs A were involved in fire at about 700 sec (11.7 minutes) while pack B was involved at 400 sec (6.7 minutes).

Observations:

- No need for vehicle fire test since no explosion and because no additional safety concern for BEVs and PHEVs compared to ICE vehicles.
- Current proposal in GTR is too short duration since Li-ion EV battery will not get involved in fire. So no explosion should be expected. Recommend eliminating the short duration test.
- Canada only evaluated a few Li-ion EV batteries. There may be other batteries such as NiMH batteries, which emit water steam when they burn, or other advanced batteries that may react differently a fire. However, there are lots of toxic gases emitted when the vehicle interior and tires burn (regardless of it being an EV or not) – so emission from battery may not be meaningful.
- Canada has never tested small hybrid Li-ion battery packs, where thermal lag during heating could be lower.
- Canada does not have another performance metric other than "no explosion" for the short term test that would be objective. It is not easy to conclusively measure/determine when cells get involved/contribute to a fire due to potential inherent safety of these cells from cell manufacturers. More than one metric will have to be used. Measuring the voltage, using pressure sensors, hydrogen/organic vapor detectors (we have done previous testing with such detectors to detect cell venting with success, however, we do not know whether it would work in the context of fire tests), as well as measuring heat rate release could all be used together although some measurement methods are intrusive which may damage the sealing of packs and affect their performance).
- Canada and US would consider a component level test (such as the UL 2580 test) if we become aware that battery explosions in BEV and PHEV vehicles is problematic. This may be in Phase 2.

Response to Questions from Korea:

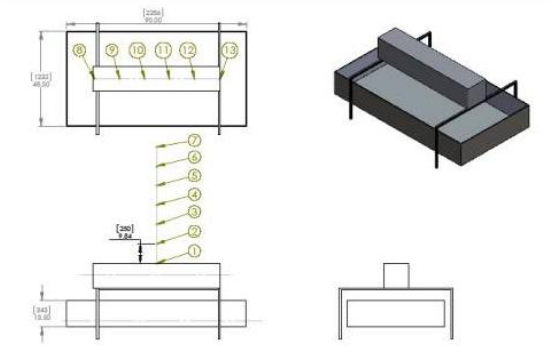
1. Position on using LPG instead of gasoline in the fire test.
    - Canada and United States do not support the use of gasoline as its composition and ethanol level vary greatly according to the seasons and the regions. Use of LPG in the fire test provides for a more repeatable and reproducible test.
2. Position on equivalency between LPG fire and gasoline pool fire.
    - Heat release rate from a gasoline pool fire varies greatly depending on the size of the fuel pan and the substrate (bare pan, water or spill fire on the ground). Additionally, the peak heat release rate occurs at a height higher than the battery packs which means the heat is not transferred into the packs. Therefore, for determining equivalence between a gasoline fire and LPG fire, Canada and United States believe temperature at the surface of the battery and the total heat release are critical criteria that should be considered. (See the *Excerpt of Previous Presentations from Canada* section)

3. Need for long duration test
    - Canada and United States recommend either (1) adopting the External Fire Exposure test of UL 2580 or (2) defer this topic to Phase 2 to allow more time for observation of real world data regarding battery explosions induced by fire.
4. Relevance of short duration test in light of Korean and Canadian test data
    - Canada and United States recommend removing the pack level short duration test in the GTR. The duration is too short for the battery to become involved in the fire and so no explosion would occur.
5. Alternative performance criterion for short duration test that would indicate the battery pack getting involved in the fire.
    - Canada evaluated and could not come up with an objective performance criterion other than an explosion one which could be defined as battery enclosure or casing opens violently, producing pressure wave and/or major components are forcibly expelled.

Excerpt of Previous Presentations from Canada

Thermocouples Positioning (Christmas Tree)

- Battery packs suspended over a propane sand burner, previously calibrated with gasoline to simulate a gasoline pool fire.



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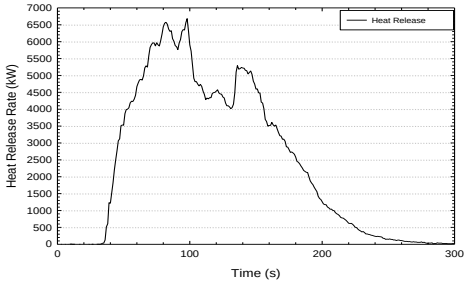
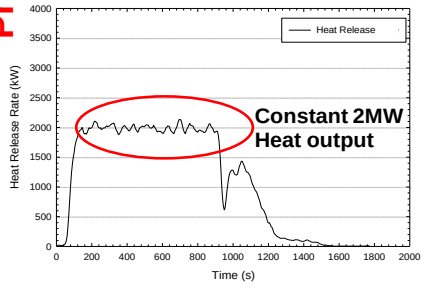
Calibration – Heat Release Rate

25L Gasoline



Propane



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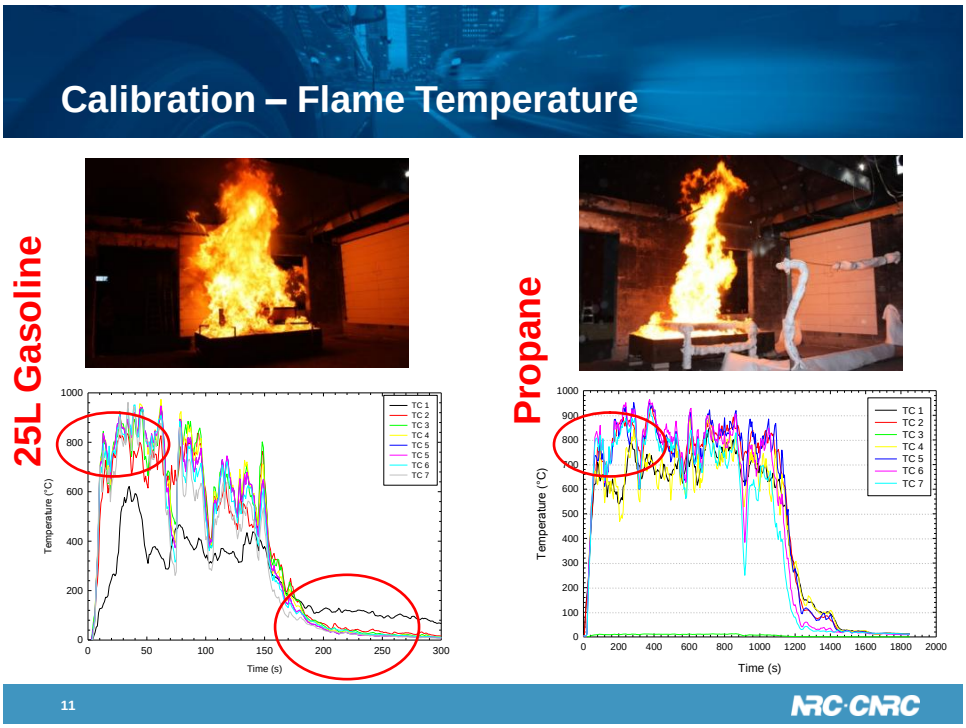
The gasoline heat release rate is higher than the propane one. The heat release rate for gasoline fires depends on a number of factors including size of pan and substrate (floated on water or spill fire). It should be possible to increase the heat release rate from an LPG fire to match the heat release rate produced by a gasoline pan fire. However, this will increase the height of the flame.



Temperatures TC 1 are taken as close as possible from the top of the battery packs. Note that the temperature TC 1 from the gasoline graph is much lower than TC 1 from the propane graph. This demonstrates that, at a close distance from the pack, the gasoline does not generate the same heat release rate as the propane. A more accurate measure of the potential impact of the fire on the battery is the temperature measured near the battery surface per UL 2580 as this determines the radiative heat flux to the battery. Another approach is to measure the incident heat flux to the battery. However, this can be difficult to measure in a flame environment.

UL2580 External Fire Exposure Test (Summary)

Fully charged REESS, heated by any fuel that provides a minimum temperature of 590°C in 5 minutes and a burn duration of 20 minutes. The REESS is covered by a mesh cage and the past/fail criterion is no explosion that results in projectiles penetrating that mesh cage.