

THERMAL PROPAGATION PACK TESTING

September 14, 2016



GENERAL MOTORS

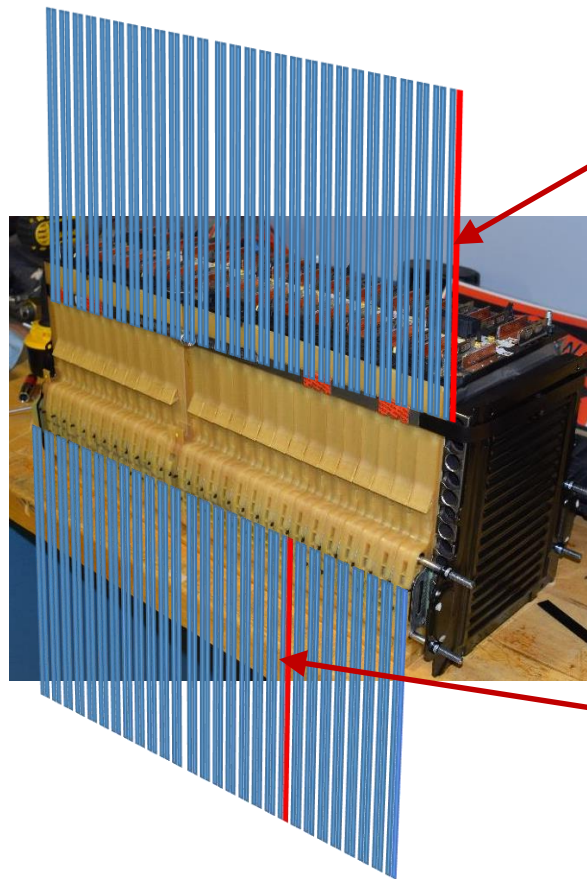
Key Conclusions

- Preparation of test article for proposed test methods is complex
 - Requires specific knowledge of internal design of pack
 - Pack changes affect test outcome
- Various options of test methodology are not equivalent
 - Proposed options necessary as no single method is applicable to all possible pack / cell configurations
 - Results show that test methodologies do not result in equivalent test outcomes

Test Plan

- Test article:
 - Non-production battery pack configuration
 - Pouch cell in a 2p28s arrangement
 - Voltage: ~116 V
 - Nominal capacity: ~52 A-hr (2 x 26 A-hr cells in parallel)
- Initiation method:
 - Block heater – 1.6 kW, constant power
 - Overcharge – 1 C rate (less than 1 hour)
- Initiation Cell Location (see following page)
 - End of pack
 - Mid pack

Initiation Cell Locations



End of Pack
Initiation Cell Location

Mid Pack
Initiation Cell Location

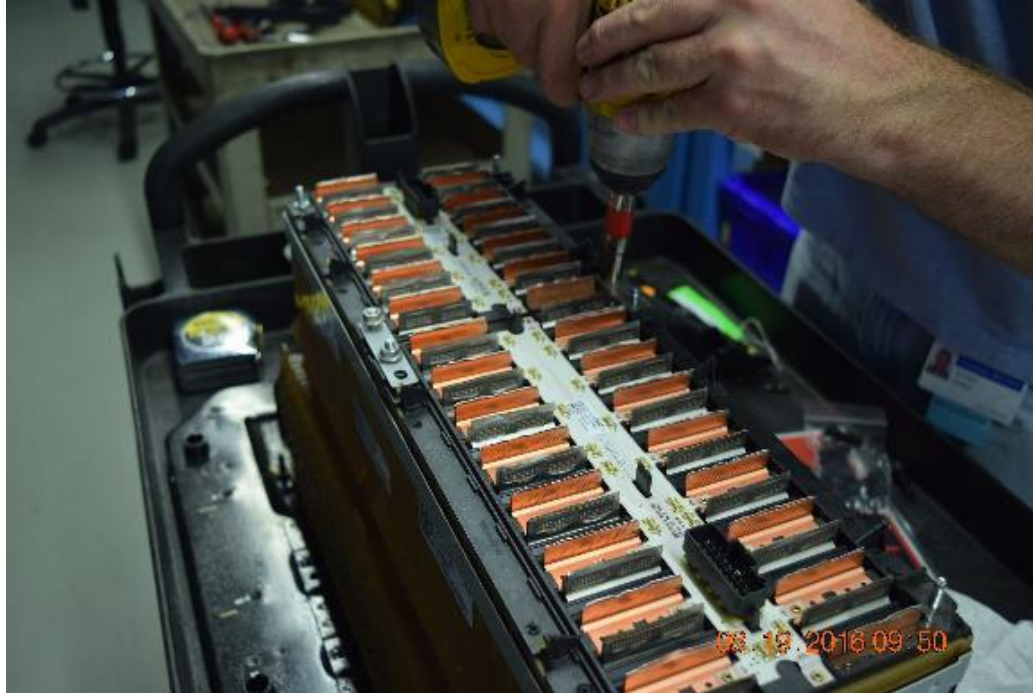
Pack modifications

Remove cover for modification

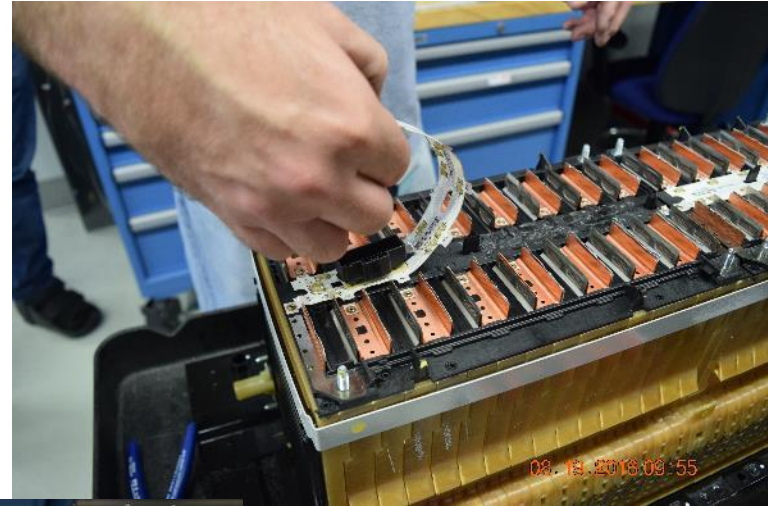


Pack cover removed

Heating – mid-pack: Remove bus bars



Heating – mid-pack: Cell sensing circuit removed

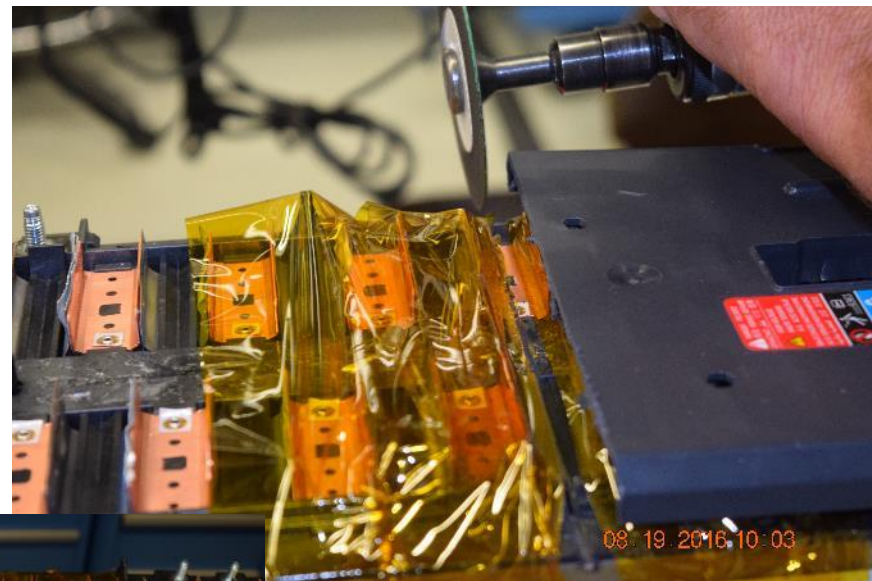
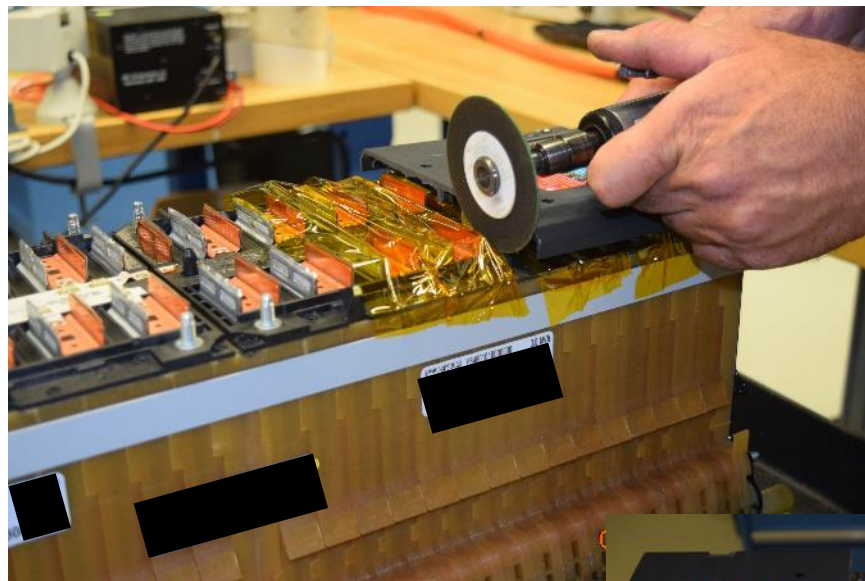


Heating – mid-pack: Preparation to cut through cell connection board



Cell connection board must be cut to insert heater

Heating – mid-pack: Cut through cell connection board



Heating – mid-pack & end-pack: Remove cell constraint fasteners



- 1) Compress stack with clamps
- 2) Remove top “strap”
- 3) Remove fasteners



Heating – mid-pack: Insertion of heater

Separate cell stack, remove holding frame,
insert heater



Separate cell stack

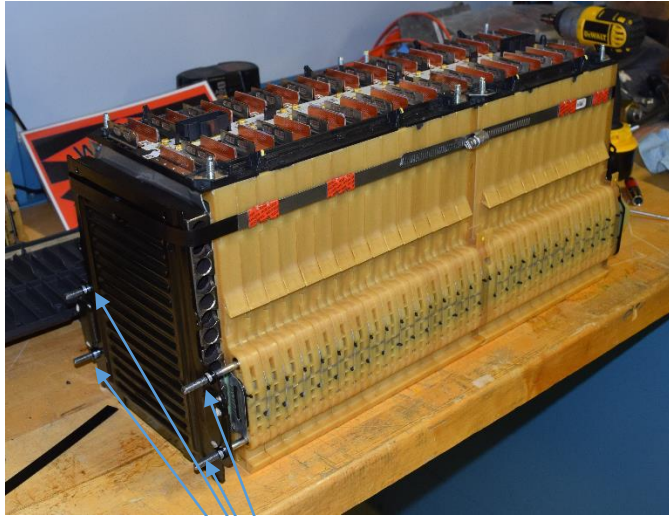


Remove holding frame
to fit heater

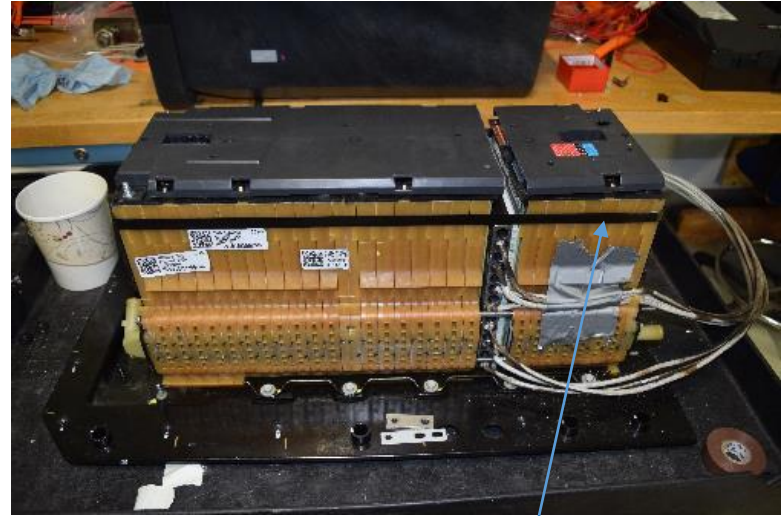


Insert heater

Heating – mid-pack & end-pack: Modification/fabrication of parts required



End-pack



Mid-pack

Longer fasteners required (both heater positions)

Larger “strap” required (both heater positions)

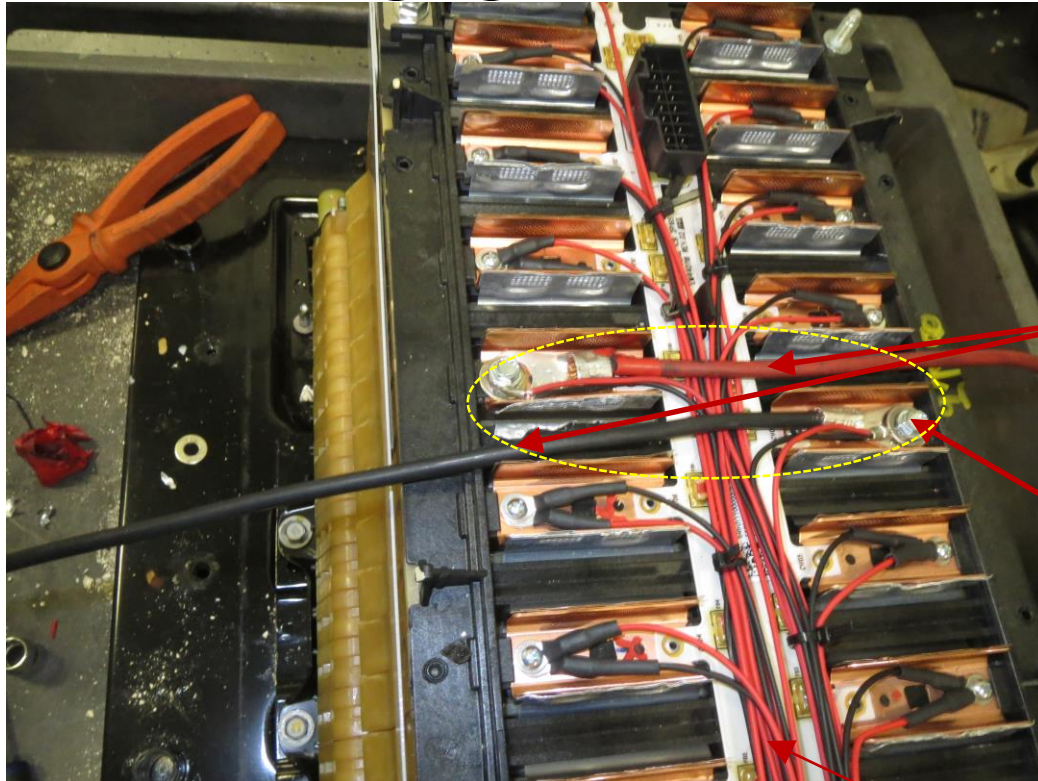
All packs:
Thermocouple fixed to target cell



Cell stack must be expanded to include thermocouple

Overcharge – mid-pack & end-pack

Install Charging Wires to Initiation Cell



Charge wires

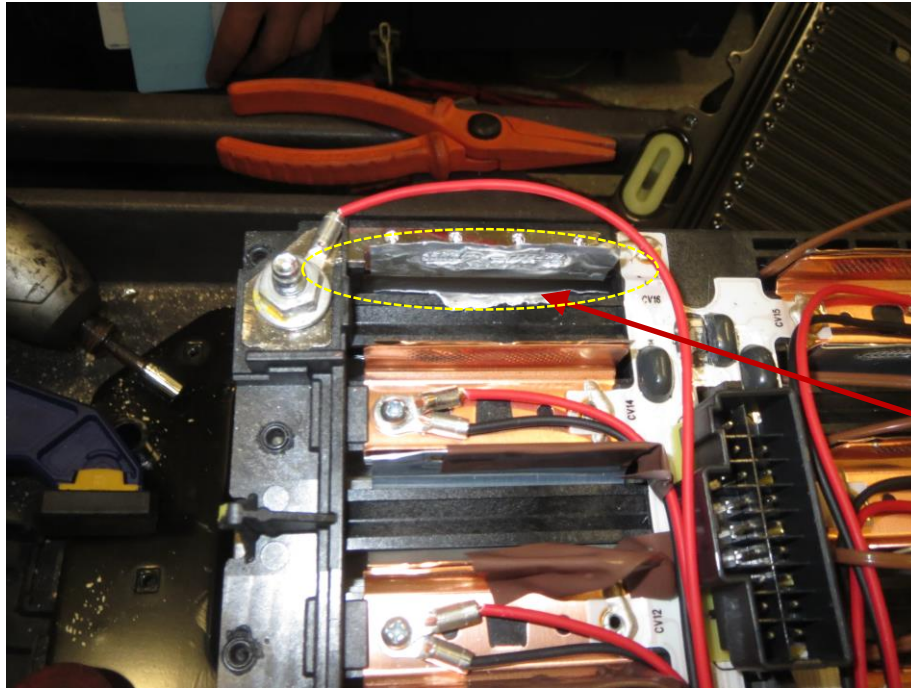
Install terminals for wire connection

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Note: Voltage measurement wires for data collection.
(Not required part of test)

Overcharge – mid-pack & end-pack




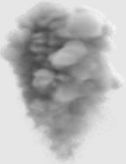

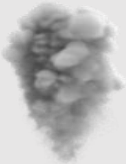

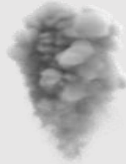
Remove parallel cell from electrical circuit











Cell tab severed to disconnect target cell from parallel configured cell pair (a single cell tab is disconnected).

Test Results

Results Summary

		End of pack	Mid pack
Heating		 Flame visible for approx. 1 second  Visible smoke D76	 Visible smoke D78
Overcharge		 Visible smoke D77	 Flame visible for >160 seconds  Visible smoke D79

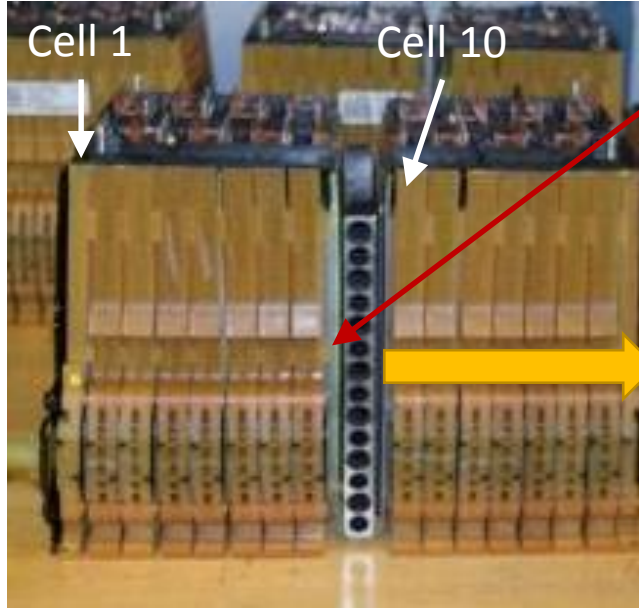
Results Summary

	D76 Heating – End	D77 Overcharge – End	D78 Heating – Mid	D79 Overcharge - Mid
Mode				
Results				
Time to all cells vent (approx. secs)	2550	2750	1950	1700
Cell groups vented* @ 300 seconds (# cells)	4	4	5	10
Cell groups vented* @ 600 seconds (# cells)	8	7	12	>13
Cell groups vented* @ 900 seconds (# cells)	12	10	14	Unknown
Cell groups vented* @1200 seconds (# cells)	15	14	16	Unknown
Cell groups vented* @ 1500 seconds (# cells)	16	16	19	Unknown
Order of voltage loss	Sequential (C1 to C28)	Sequential (C1 to C28)	C9, C10, C11, C12, C13, C8, C14, C7, C15, C6, C16, C5, C4, C3, C1, C17, C18, C19, C20, C21, C22, C23, C24, C25, C28, C26, C27	C9, C8, C10, C7, C11, C6, C5, C12, C4, C3...cannot be distinguished.
*Voltage loss of the cell group is assumed indicative of cell venting				

See next page for explanation.

Example of influence of test set-up on results

Mid pack, Heater



Insulating plate to prevent heater from initiating 2 cells.

Initial propagation direction (4 cells)

Summary

- Testing conducted by General Motors illustrates that the proposed thermal propagation test is not currently suitable for regulation.
 - Outside test agencies will not have the specific background necessary to complete test preparation
 - Modifications required for testing affect the test outcome
 - The various options available within the proposed test are not equivalent
- The alternative strategy requiring documentation, as proposed by the USA (NHTSA), is more appropriate for the EVS-GTR in Phase 1.