CHEVROLET BOLT BATTERY ELECTRIC VEHICLE (BEV)
LOW TEMP EV &
BATTERY/CABIN PRE-CONDITIONING RESULT

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AGENDA

- **Introduction to Test Vehicle**

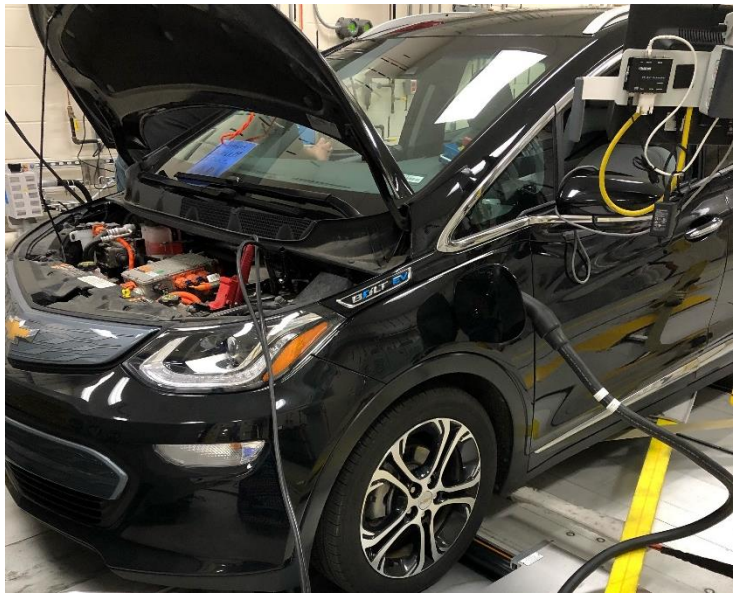
- **Low Temp EV Drive Schedule (-7°C)**
  - Without Pre-Conditioning
  - With Pre-Conditioning

- **Chevrolet Bolt Test Results - Comparison of Test Methods**
  - Pure Electric Range (PER) Reduction at -7°C
  - Electric Consumption
  - HV Battery Capacity Loss

- **Customer Behavior Considerations**

Introduction to Test Vehicle

Vehicle: Chevrolet Bolt EV



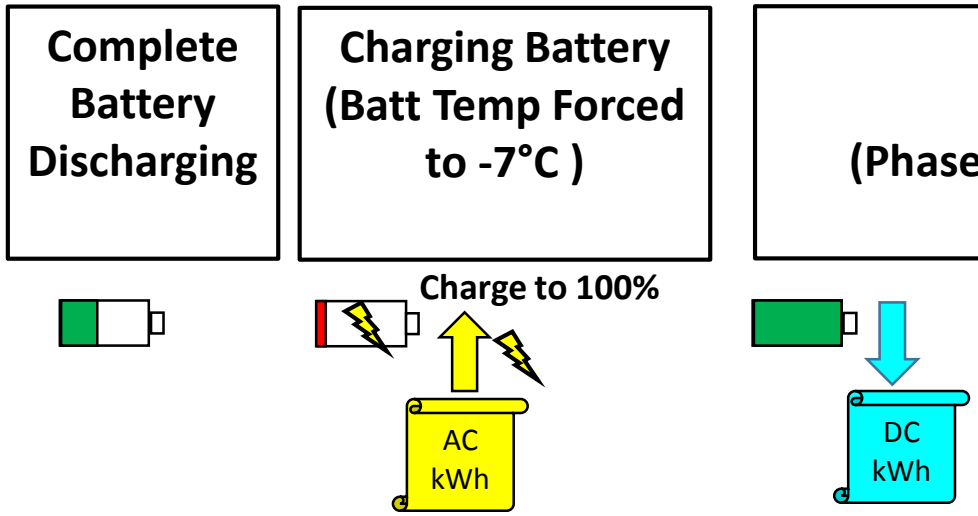
- Facility: Milford Proving Grounds Emissions Lab (Milford, MI)
- Engineering development vehicle
- Instrumented Controllers
  - Allow more data capture
  - Pre-conditioning programming via calibration change
- 4.4 kW Mobile Vehicle Charger & Energy Measurement Station
  - for vehicle charging and dyno pre-conditioning

Test Objectives

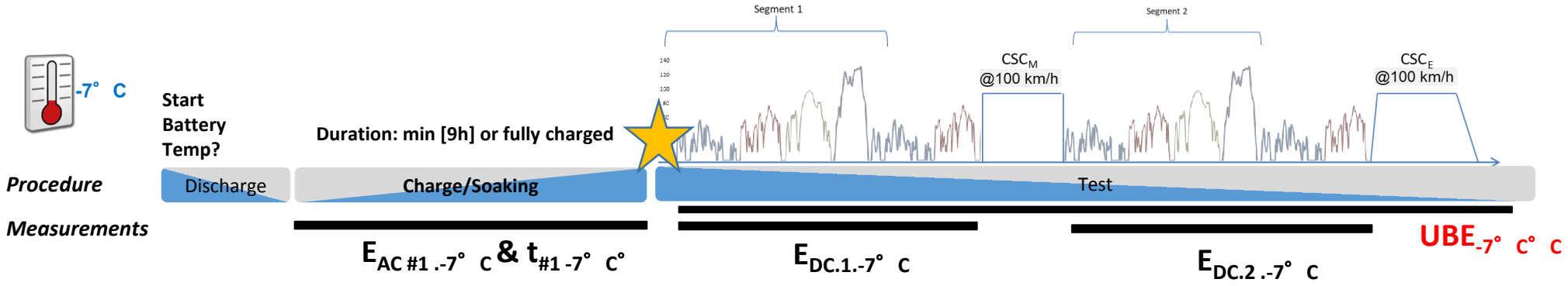
- Quantify electric vehicle range at -7°C ambient and PER ratio
  - with and without pre-conditioning
- Quantify HV Battery Useable Capacity Loss vs. Ambient Temperature

-7°C Ambient: WLTP-STP No Pre-Conditioning

WLTP-STP: No Battery/Cabin Pre-Condition Prior to Test



Bolt was intentionally conditioned to have -7°C battery at start of test.

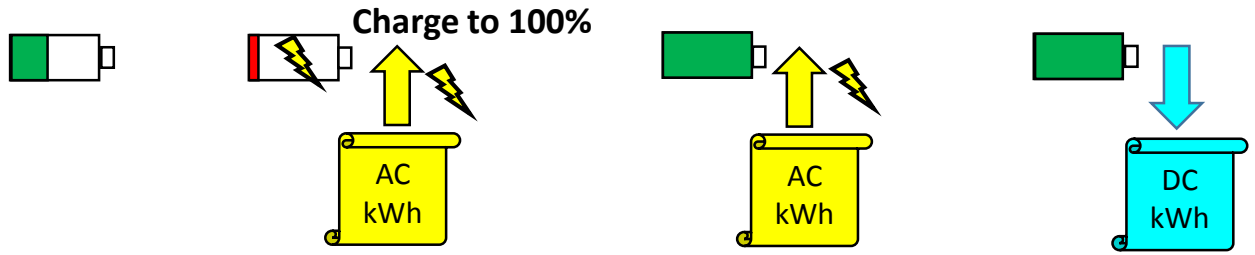


No Pre-Condition: $E_{AC\ FINAL} = E_{AC\ \#1}$

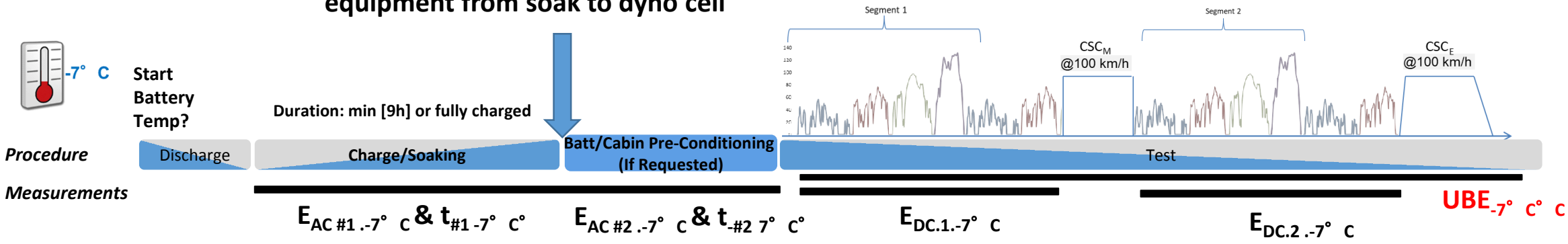
-7°C Ambient: WLTP-STP With Pre-Conditioning

WLTP STP: With Battery/Cabin Pre-Condition Prior to Test

Complete Battery Discharging	Soaking, Charging Battery, (Batt Temp Forced to -7°C)	Cabin & Battery Pre-Condition	Drive Schedule (Phase Efficiency, UBE Determination)



Move charge measurement equipment from soak to dyno cell



Pre-Condition: $E_{AC\ FINAL} = E_{AC\ \#1} + E_{AC\ \#2}$

Comparison of Methods: Pre-Conditioning vs. No Pre-Conditioning

No Pre-Conditioning → Up to 4% Test-to-Test Variation

With Battery and Cabin Pre-Conditioning → Less Than 1% Test-to-Test Variation

- Energy measurement prior to WLTP-STP to ensure pre-conditioning energy is captured (if preconditioning is applied)
- It needs to be ensured that battery temperature set point prior to WLTP is repeatable:
  - Variable HV battery temp before WLTP-STP can influence HV battery useable energy (capacity)
  - Starting temp before discharge prep can influence WLTP-STP HV battery test temperatures
  - Time between charge complete and start of WLTP-STP procedure can influence battery temperatures
  - <u>Possible Options</u>:
    - In case of battery pre-conditioning: Allow vehicle to stay plugged in until start of WLTP-STP to ensure a reproducible battery temperature at the start of the test
    - In case of no battery pre-conditioning: defined temperatures to be reached before charging/soaking
- If cabin conditioning is used, defined conditions for the application are required

-7°C Ambient: No Pre-Conditioning vs. Pre-Conditioned Battery + Cabin - Chevrolet Bolt

- Pre-Conditioning the vehicle prior to test had noticeable effects on Range / UBE
- AC Energy consumption was high due to low battery insulation (can improve in future)
  - Ideally near 1:1 tradeoff desired with pre-conditioning: % AC Energy Increase = % Range Increase

-7°C WLTP-STP Comparison	With Battery + Cabin Pre-Conditioning vs. Without Battery or Cabin Conditioning Chevrolet Bolt
% Diff Electric Consumption [AC kWh / 100 km]	12.5% More AC Energy Consumption due to Pre-Conditioning
% Diff Electric Consumption [DC kWh / 100 km]	2.2% Less DC Energy Consumption due to Pre-Conditioning
% Diff PER [km]	6.5% More Range due to Pre-Conditioning
% Diff - Useable Energy [kWh]	4.2% More UBE due to Pre-Conditioning

Battery Pre-Conditioning Time: 4 hours after charge complete (-7°C forced charging temp)

- Ideally this step could occur during charging

Cabin Pre-Conditioning Time: 30 mins prior to WLTP-STP

- Limit time to ~ 1 hr. to avoid excess dyno usage

-7°C Ambient: Battery Capacity and PER Reduction – Chevrolet Bolt

- Pre-Conditioning the vehicle prior to test shows 4% PER ratio change
- Noticeable battery capacity change between -7°C and 25°C depending on if pre-conditioning used
- Pre-Conditioned Battery will still incur capacity loss at -7°C due to increased C-rate from 10% additional roadload, cabin heater and pack heat loss

PER Range Reduction	WLTP-STP	
	Without Battery and Cabin Pre-Condition	With Battery and Cabin Pre-Condition
% PER has reduced at -7°C Compared to 25°C	41%	37%

Battery Capacity Change vs. Pack Temperature	WLTP-STP @ -7°C	
	Without Battery Pre-Conditioning (-7°C Pack Temp)	With Battery Pre-Conditioning
Useable Battery Energy (UBE) Degradation As Compared to 25°C Battery	6.7% Loss	2.8% Loss

-7°C Ambient: Customer Behaviors To Take Into Consideration

Vehicle Remains Plugged Overnight to Charge, Remains Plugged In After Charging:

- Overnight charging event
- HV Battery Does/Does Not Maintain Temperatures well above ambient temperature while plugged in (using AC energy)
- Customer Does/Does Not Request Cabin Warmup prior to driving (“Remote Start”)
- Customer Drive Distance: Long vs. Short
  - Long Distance Customer Benefits Most From Pre-Conditioning
  - Short Distance Customer Less Concerned With Range Loss on Full Battery