CHEVROLET BOLT BATTERY ELECTRIC VEHICLE (BEV)
WLTP FUTURE TEST IMPROVEMENTS
TA / LOW TEMP EV

28th WLTP IWG – 25th September 2019

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AGENDA

- **Benefits of Shorter Test Method For Determination of Range in the Future**
- **Introduction to This Shorter Test Method for "Long Range" PEVs**
- **Comparison of Results from Shorter Test Method and WLTP-STP @ -7°C Ambient**
  - Electric Range and Useable Battery Energy (UBE)
  - With and Without Pre-Conditioning
- **Comparison of Results from Shorter Test Method and WLTP-STP @ 25°C Ambient**
  - Electric Range and Useable Battery Energy (UBE)
- **% PER Reduction @ -7°C: Comparison of Methods**
- **Useable Battery Energy (UBE): Comparison of Methods**

Why Shorten BEV Testing in the Future for WLTP?

- WLTP-STP first introduced to reduce test time of PEVs (compare to consecutive cycle method)

- BUT:
  - Electric range of PEVs will increase with time
  - Resulting testing time using WLTP-STP will increase significantly with increasing electric range

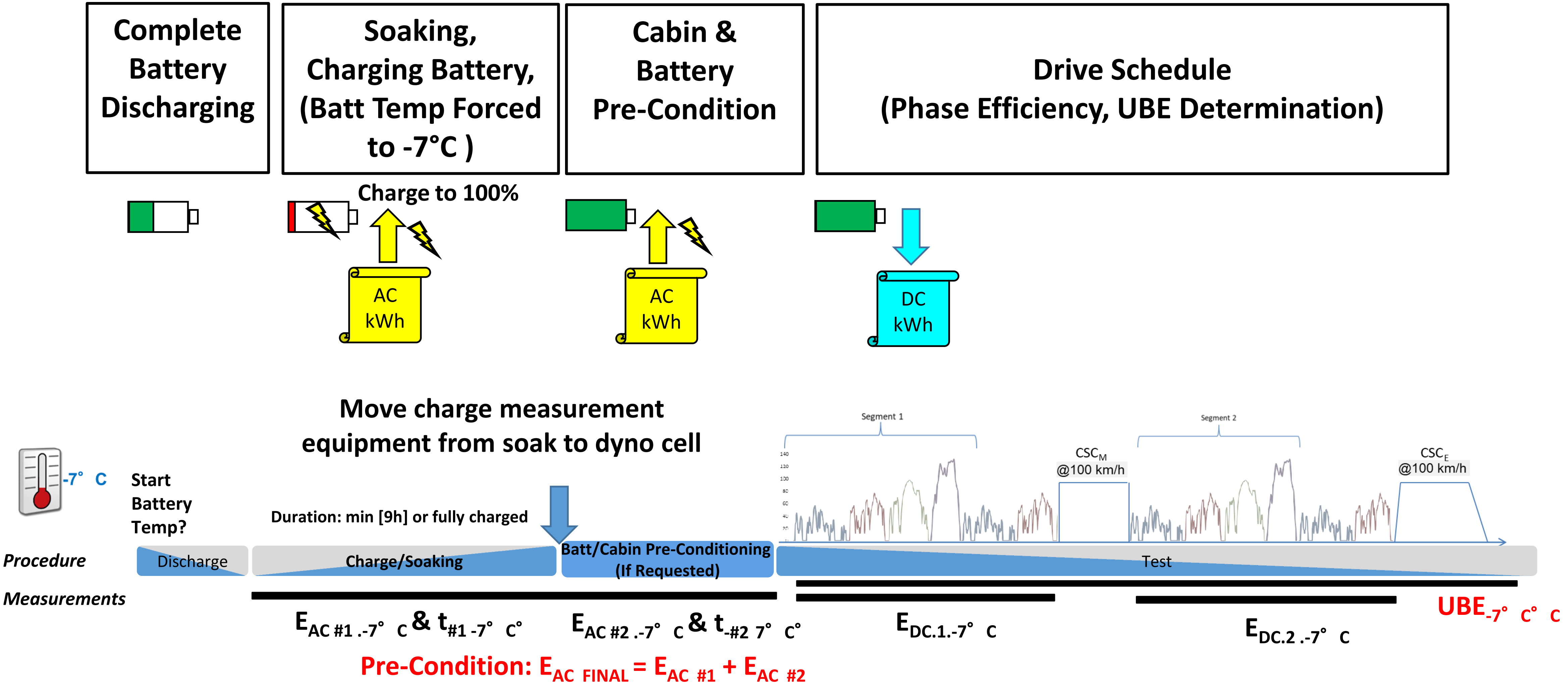
- Shortened Method in Content of Low Temp:
  - Can be independently applied to Low Temp (at the moment)
  - In future, can be applied in combination with 23°C temperature condition
    - Would allow for identical setup between -7°C and 23°C temperature conditions

- To Avoid Method Equivalency, Implementation of Shorter Method With Threshold Concept:
  - Similar to WLTP-CCP and WLTP-STP thresholds to determine test type to run
  - Based on range of vehicle:
    - Low Range Vehicle → Medium Range Vehicle (Threshold 1): CCP to STP
    - Medium Range Vehicle → Long Range Vehicle (Threshold 2): STP to Shortened Method (NEW)

- If there is a WLTP Phase 3 → Discuss Shortened Method for both -7°C and 23°C conditions

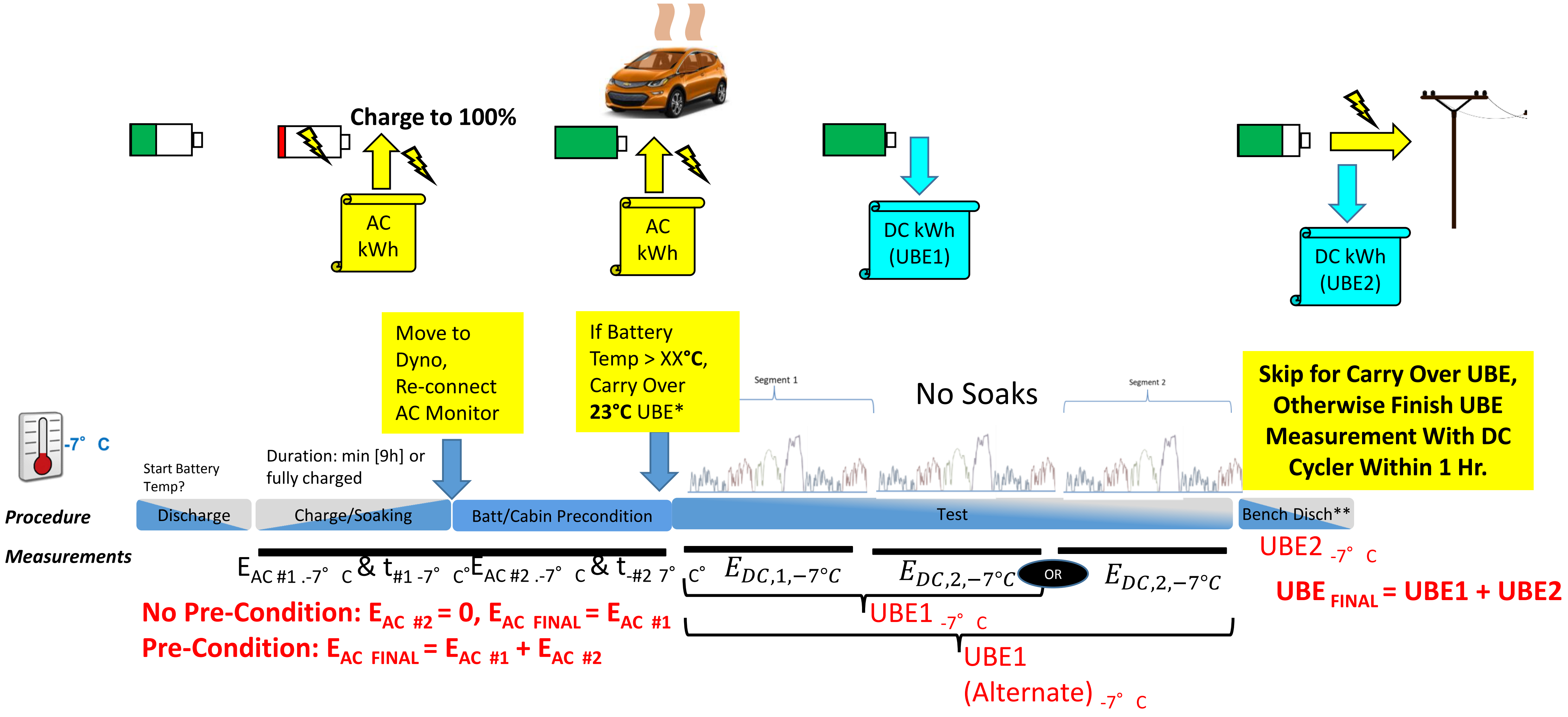
-7°C Ambient: WLTP-STP With Pre-Conditioning

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



-7°C Ambient: WLTP Short Test – Detail View

WLTP Short Test with 6-Phase Only: With or Without Battery/Cabin Pre-Condition Prior to Test (Short Dyno Test)



*Optional: Carry over UBE is recorded from WLTP-STP TA test at 23°C (assuming battery discharge window matches between -7°C and 23°C)

**Leverage DC cycler as alternative to record -7°C UBE to save dynamometer time

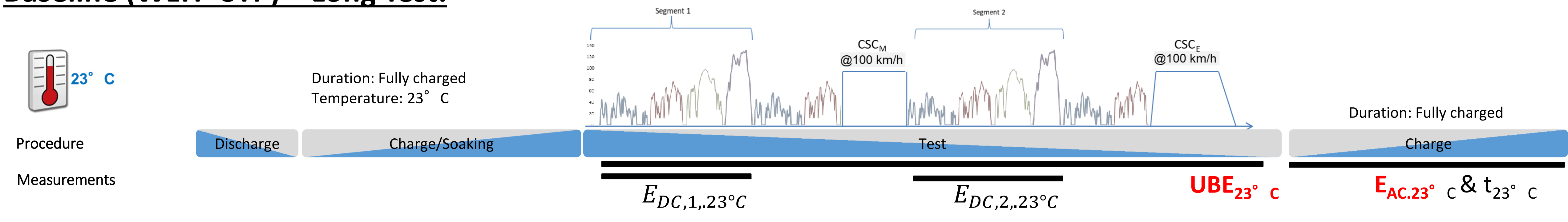
-7°C Ambient: Comparison of Long vs. Short Test Results - Chevrolet Bolt

-7°C WLTP Comparison	% Difference WLTP Short (6-Phase Only) vs. WLTP-STP	
	No Battery or Cabin Pre-Conditioning Short Test vs. WLTP STP	With Battery + Cabin Pre-Conditioning Short Test vs. WLTP STP
% Diff Electric Consumption [DC kWh / 100 km]	0.2% Less Consumption on Short Method	0.8% More Consumption on Short Method
% Diff PER [km] Initial Target: < 1% Absolute	0.3% Less Range on Short Method	1.1% Less Range on Short Method
% Diff - Time on Dyno [Hour] Target: ~-50%	60% Less Time on Short Method	40% - 60% Less Time on Short Method
% Diff - Useable Energy [kWh] Initial Target: < 1% Absolute DC Cycler Rate: ~9 kW	0.51% Less UBE on Short Method	0.37% Less UBE on Short Method

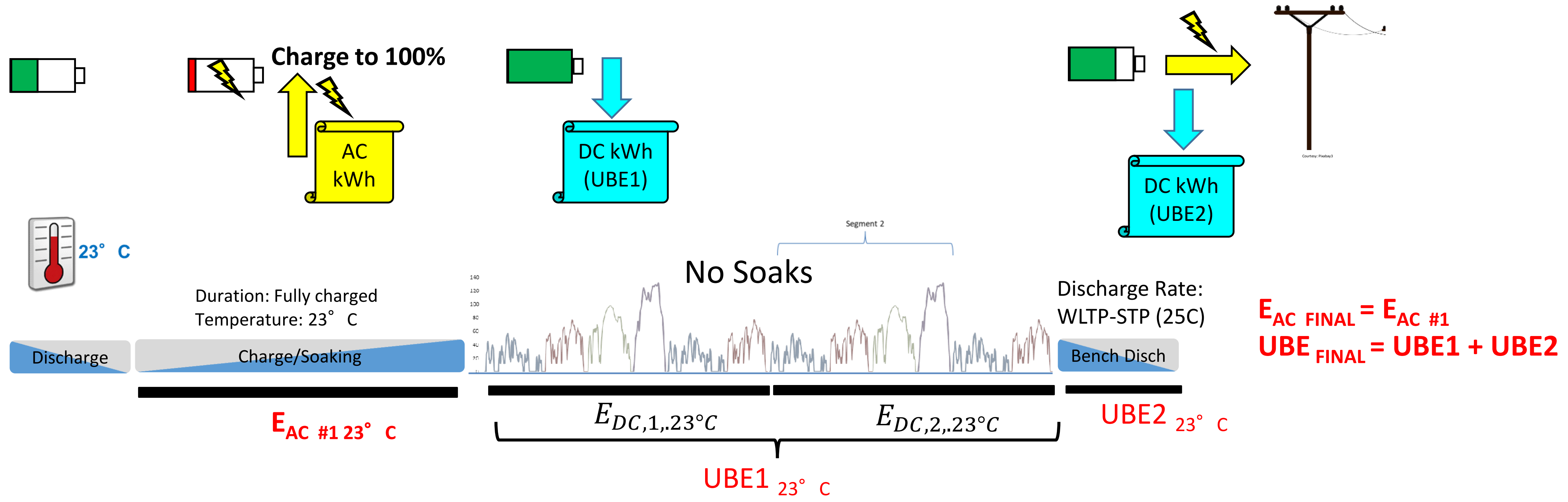
- No pre-conditioning: Short Test is able to meet < 1% PER criteria vs. WLTP-STP using a shorter drive cycle/DC cycler
- With pre-conditioning: Short Test is slightly over 1% PER criteria
  - Not due to UBE measurement which is below 1% criteria
- With better insulated battery, < 1% PER criteria could be achieved with the pre-conditioning method

23°C Ambient: WLTP-STP and WLTP 2x 6-Phase Correlation

Baseline (WLTP-STP) – Long Test:



Shortened WLTP 2x 6-Phase Test (1.6 hr. dyno test) + DC Cycler:



25°C Ambient: Comparison of Long vs. Short Test Results - Chevrolet Bolt

25°C WLTP Comparison	% Difference 2x 6-Phase Only + DC Cycler (Short Test) vs. WLTP-STP (Standard Test)
% Diff Electric Consumption [DC kWh / 100 km]	0.9% Less DC Energy Consumption Using Shortened Method
% Diff PER [km] Initial Target: < 1% Absolute	0.3% Improved Range Using Shortened Method
% Diff - Time on Dyno [Hour] Target: ~-50%	68.6% Shorter Test Duration Using Shortened Method
% Diff - Average Discharge Rate During Test [kW]	0 (Rate 12.5 kW)
% Diff - Useable Energy [kWh] DC Cycler Rate: WLTP-STP Initial Target: < 1% Absolute	0.68% Less UBE Using Shortened Method

- Shorter Test Method is able to meet < 1% PER criteria vs. WLTP-STP using a shorter drive cycle/DC cycler
- DC cycler is capable of meeting < 1% UBE delta to WLTP-STP test

Chevrolet Bolt WLTP PEV Test Summary
% PER Reduction @ -7°C

PER Range Reduction	STP		Short Test (NEW)	
	Without Pre-Condition	With Pre-Condition	Without Pre-Condition	With Pre-Condition
% PER has reduced at -7°C Compared to 25°C	41%	37%	41%	38%

Result:

- No Pre-Condition: Equivalent range reduction WLTP-STP compared to Shortened Method
- With Pre-Condition: Within 1% range reduction WLTP-STP compared to Shortened Method
- 40 – 60% less time on dyno to achieve results with short test @ -7°C
- 70% less time on dyno to achieve results with short test @ 25°C

Chevrolet Bolt – Carry Over UBE 25°C vs. -7°C

	WLTP-STP Method (UBE kWh)	Short Cycle + DC Cycler Method (UBE kWh)
25°C UBE	Baseline For This Column WLTP-STP Discharge Rate (12.5 kW)	Baseline For This Column, WLTP-STP Discharge Rate (12.5 kW)
-7°C UBE With Pre-Conditioned Battery	2.8% Loss in UBE	2.8% Loss in UBE WLTP Short Test Discharge Rate, 8.8 kW
-7°C UBE Without Pre-Conditioned Battery	6.7% Loss in UBE	6.6% Loss in UBE WLTP Short Test Discharge Rate, 8.8 kW

- **Meets** 5% UBE rule from SAE J1634 draft for pre-conditioned battery at or below 20°C.
- **Did Not Meet** 5% UBE rule from SAE J1634 draft for non pre-conditioned battery at -7°C

- DC Cycler methods show that a full discharge is not needed to achieve final UBE @ -7°C,

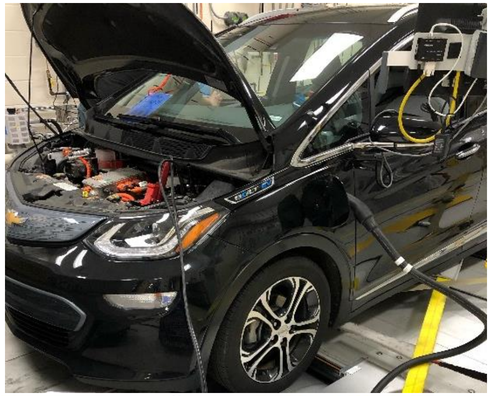
can piece together from WLTP DC energy and remaining from DC cycler, which saves test time

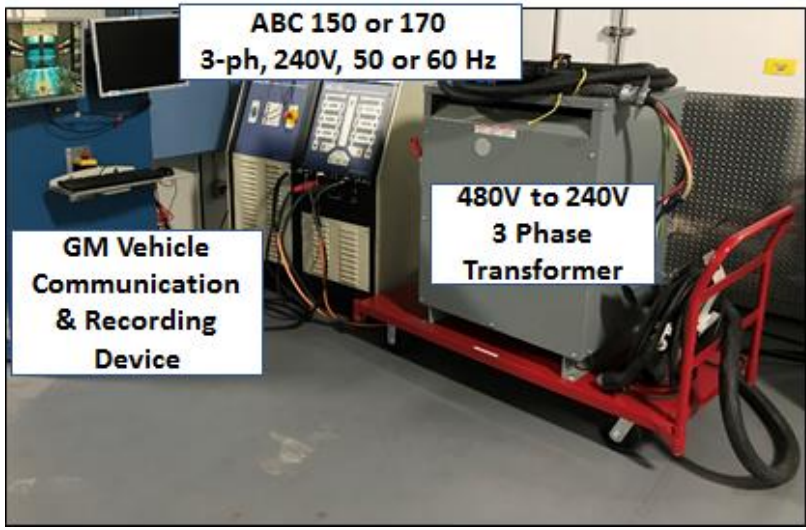
BACKUP

Short Test Method Equipment for Long Range BEVs

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
- **Add: 7.4 kW Mobile Vehicle Charger & Energy Measurement Station**
  - **25°C tests**
- **Add: ABC 150 or ABC 170 can be used for discharging HV battery to measure Useable Battery Energy (UBE)***
  - Many different publicly available brands to choose from
- 4.4 kW Mobile Vehicle Charger & Energy Measurement Station
  - for vehicle charging and dyno pre-conditioning (-7°C tests only)





*GM does not endorse a specific hardware set for this procedure

-7°C Ambient: WLTP-STP vs. WLTP Short – Chevrolet Bolt Comparison

	WLTP-STP	WLTP Short + DC Cycler (No Steady State)
Dynamometer Test Duration	3.9 hr.	1.6 - 2.4 hr.
Energy Measurement Equipment	DC Monitor (Driving) AC Monitor (Charging)	DC Monitor (Driving) DC Cycler (Discharging)* AC Monitor (Charging)
Pre-Conditioning Equipment	AC Monitor (Charging)	AC Monitor (Charging)

*Approximate payoff period with dyno session cost savings: 2-4 months

	No Pre-Conditioning	Pre-Conditioning
HV Battery Temperature During Soak	~1°C per hour loss	Stable
Start of Test HV Battery Temperature	Variable	Stable
Range Test Repeatability With Variable Soak Time	**Up to 4% Variation**	Less Than 1% Variation