Power Determination Test Procedure Validation Program

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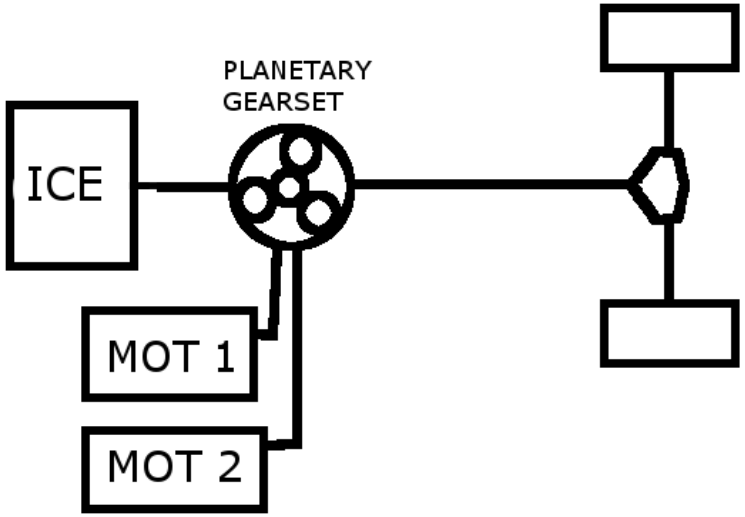
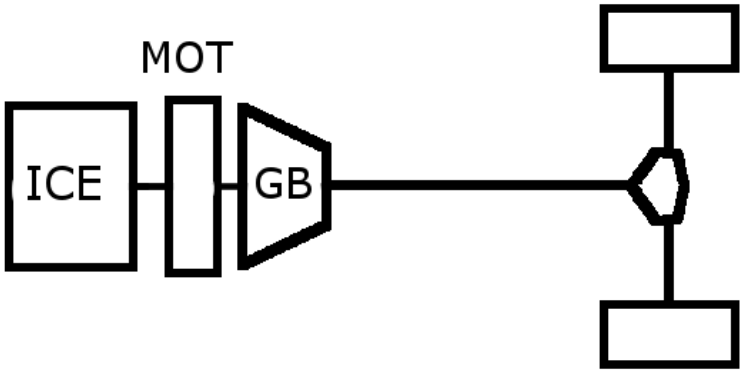
Vehicle Description

2016 GM Volt



- 158 km/h top speed
- 75kW Engine
- 110kW Motors combined

2018 BMW 530e



- 235 km/h top speed
- 134kW Engine
- 83kW Motor
- 185kW Total rated power

Vehicle Settings

2016 GM Volt

- Hood closed
- Disable TC 

- Select Sport mode
- Use ‘Hold’ mode for warmup
- Use EV mode for testing

2018 BMW 530e

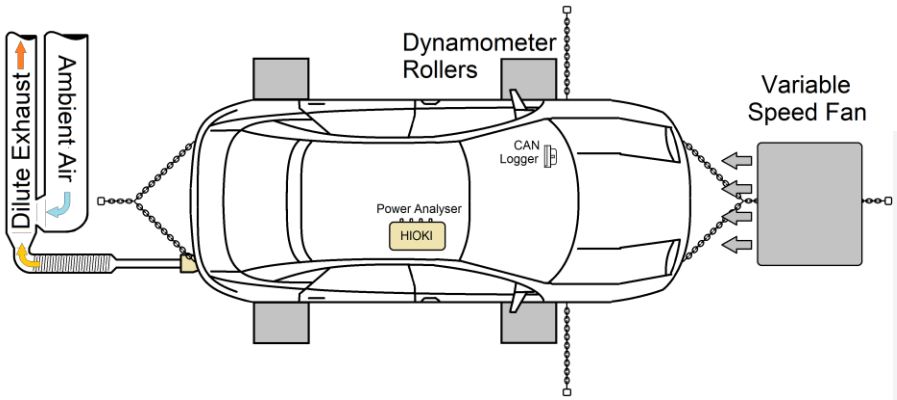
(1)

(2)

(3)

Instrumentation and Measurements

- HIOKI 3390-10 power analyzer with HIOKI CT6843 200A probes
- CAN OBD logging
  - GM Volt: OEM Scantool – GM MDI 2
  - BMW 530e: Diagra-D
- Chassis Dyno (in-house designed, fabricated and programmed)
  - GM Volt: 200hp 48in 2WD dyno
  - BMW 530e: 400hp 48in AWD dyno (rear/front master)
- Graphtec GL800 datalogger



Instrumentation and Measurements

- HIOKI 3390-10 power analyser and HIOKI CT6843 probes (20Hz logging)
  - GM Volt: Motors, DC-DC converter, onboard charger, heater, A/C compressor currents, with high voltage and 12V voltages
  - BMW 530e: High voltage battery terminal (+'ve and –'ve) current only
- CAN OBD logging - BMW 530e using Diagra D (~1Hz logging)

1. Calculated load [%]
2. Engine coolant temp [degC]
3. Intake manifold pressure [kPa]
4. Engine speed [rpm]
5. Vehicle speed [kph]
6. Air flow rate [g/s]
7. Absolute throttle [%]
8. Lambda
9. Relative throttle [%]
10. Ambient temp [degC]
11. SOC [%]
12. Engine oil temp [%]
13. Intake air temp [degC]
14. Catalyst temp [degC]

Instrumentation and Measurements

- CAN OBD logging – GM Volt using MDI 2 (100hz logging)

1. Engine speed [rpm]
2. Vehicle speed [kph]
3. Power mode
4. Ignition off/on/start
5. SOC [%]
6. HV battery current [A]
7. Max HV battery temp [C]
8. Min HV battery temp [C]
9. Regen torque [Nm]
10. Engine Torque [Nm]
11. Axle torque [Nm]
12. Brake torque [Nm]
13. Engine running [bit]
14. Calculated throttle pos [%]
15. Motor 1 current [A]
16. Motor 2 current [A]
17. Motor 1 voltage [V]
18. Motor 2 Voltage [V]

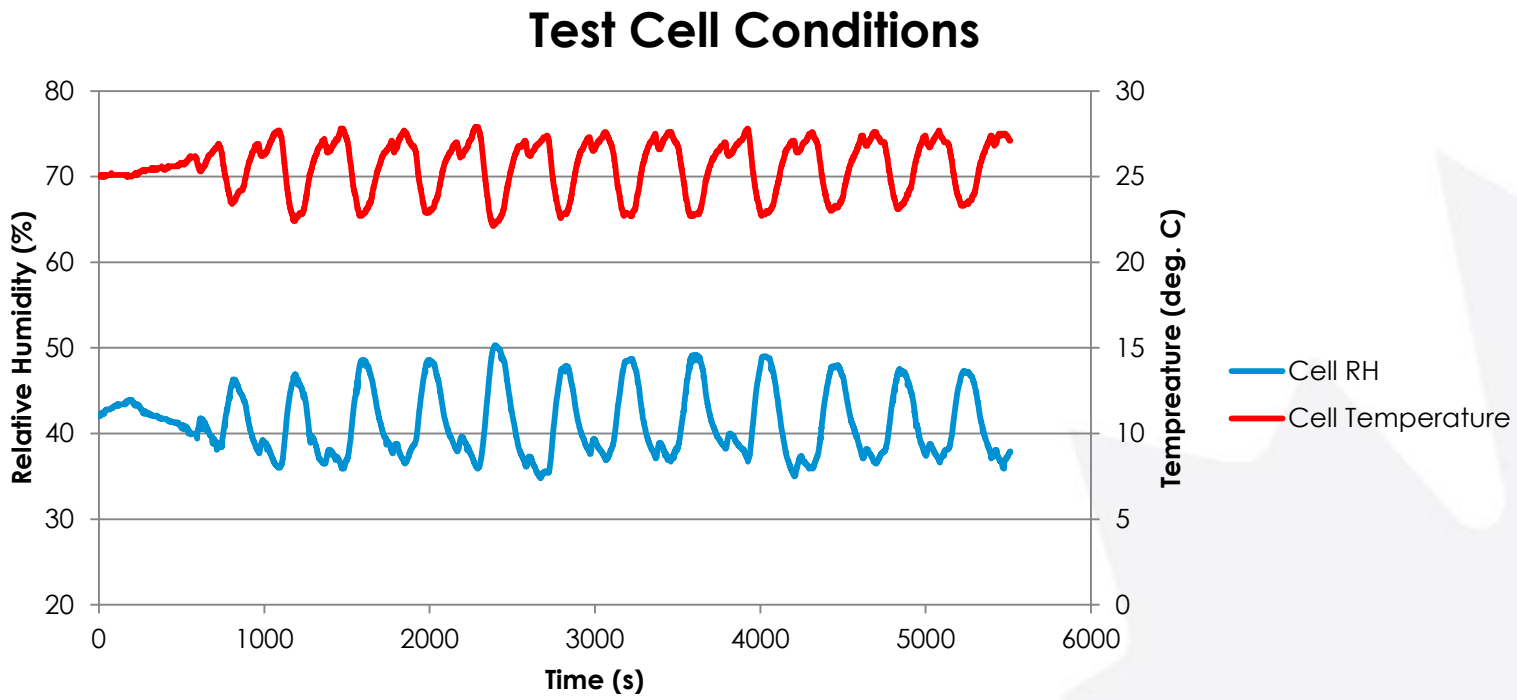
Instrumentation and Measurements

- Chassis Dyno (100hz logging)

Dyno	Cell 2	Cell 4
Max Speed	145 km/h	Same
Max steady-state wheel load	6200 N	6200 N per axle
Short time absorption (30sec)	225 kW	225 kW per axle
Continuous absorption	150 kW	150 kW per axle
Rolls	**Cell 2**	**Cell 4**
Material	Steel	Steel
Diameter	121.9 cm	120.65 cm
Width	309.9 cm	317.5 cm
Spacing	71.1 cm	80 cm
Surface Finish	Machine cut lathe	Same
Wheelbase	N/A	2.3m – 3.9m

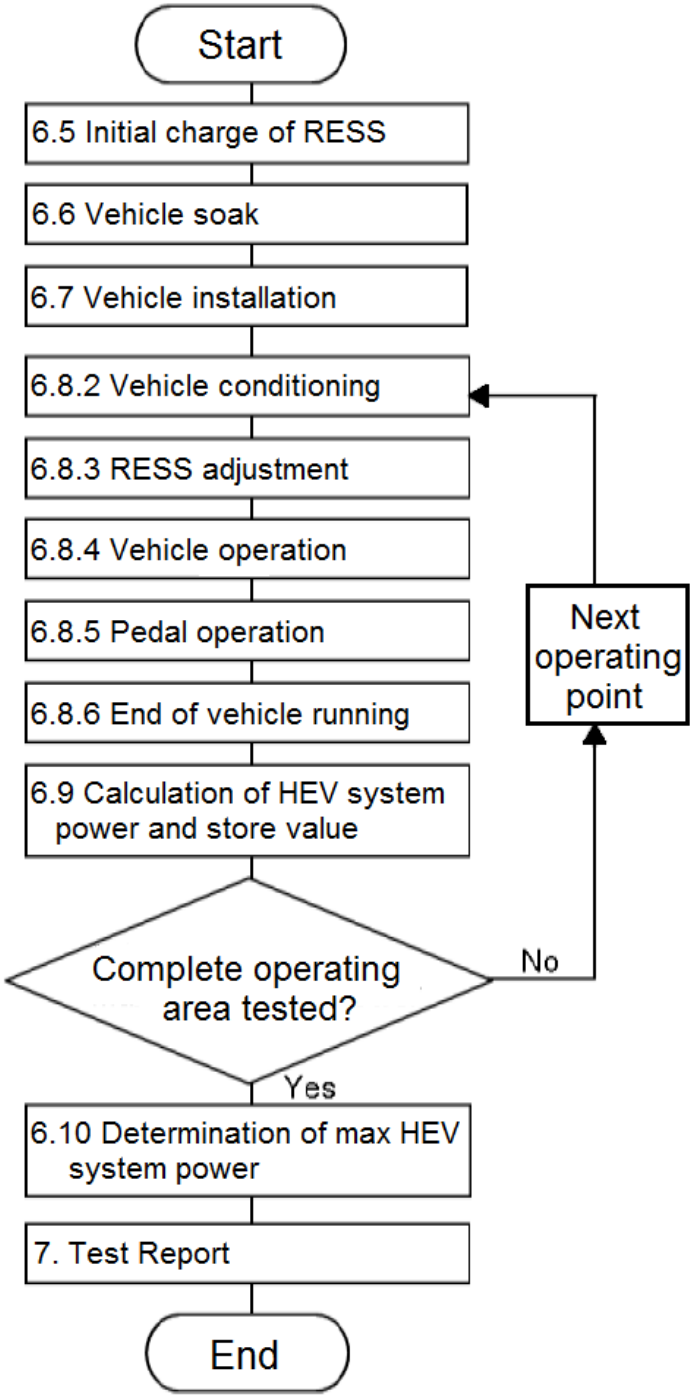
Instrumentation and Measurements

- Graphtec GL800 datalogger (1hz logging)
  - Amb Temp: Omerga type-T thermocouple
  - Rel. Hum. : Graphtec B-530 humidity sensor

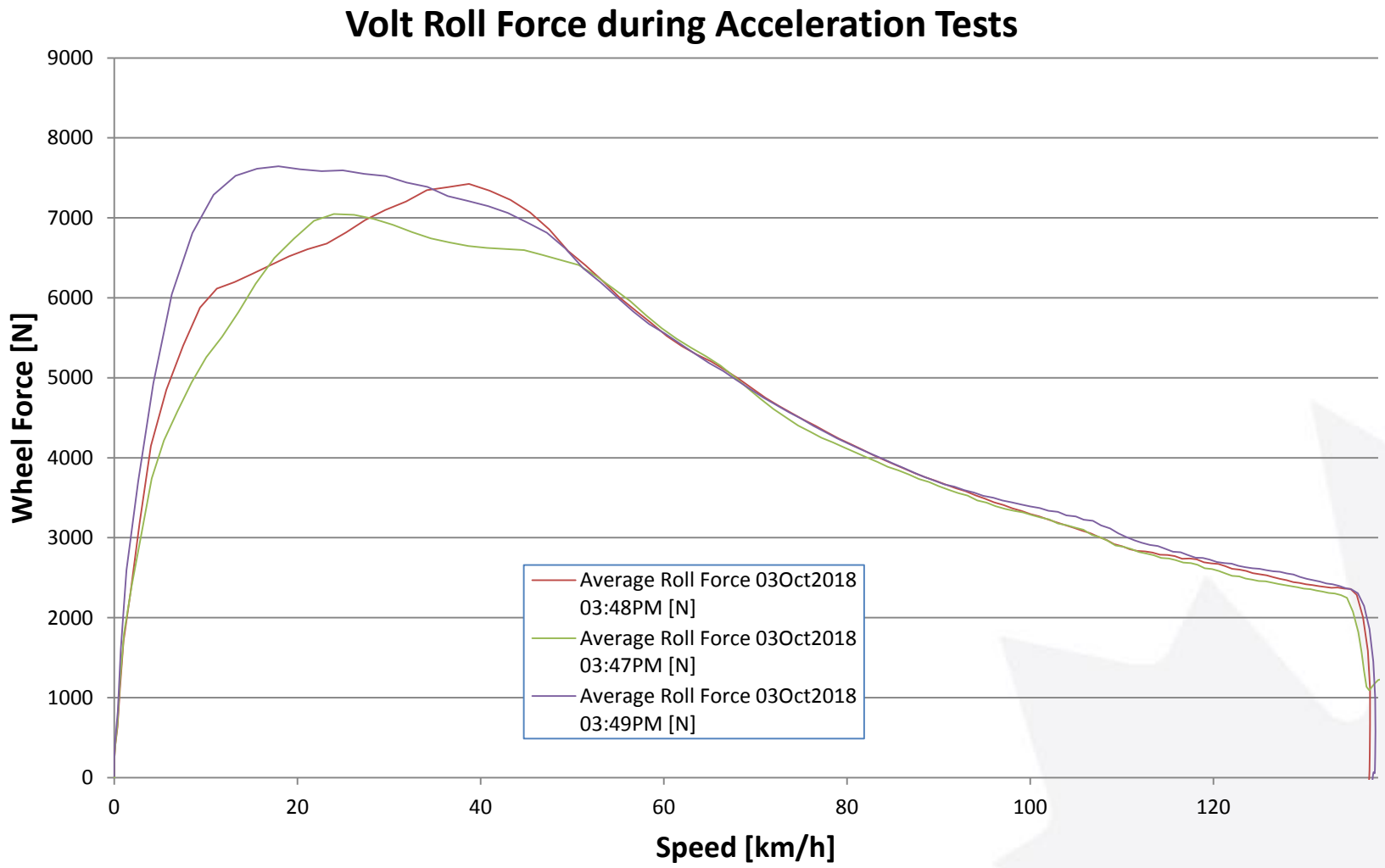


Test Overview

- Before conducting the fixed speed tests, ERMS ran several full throttle acceleration tests to get a comparison power curve like on a standard “tuning shop” dyno
- Next we conducted the test procedure in the GTR using steady-speed 10 second full-throttle segments
- We used speed increments of 10kph in a first pass sweeping from 50 to 130 or 140 km/h and then 2.5 km/h increments in a second sweep of the speed area near max power



GM Volt Test Results – Preliminary Acceleration Tests



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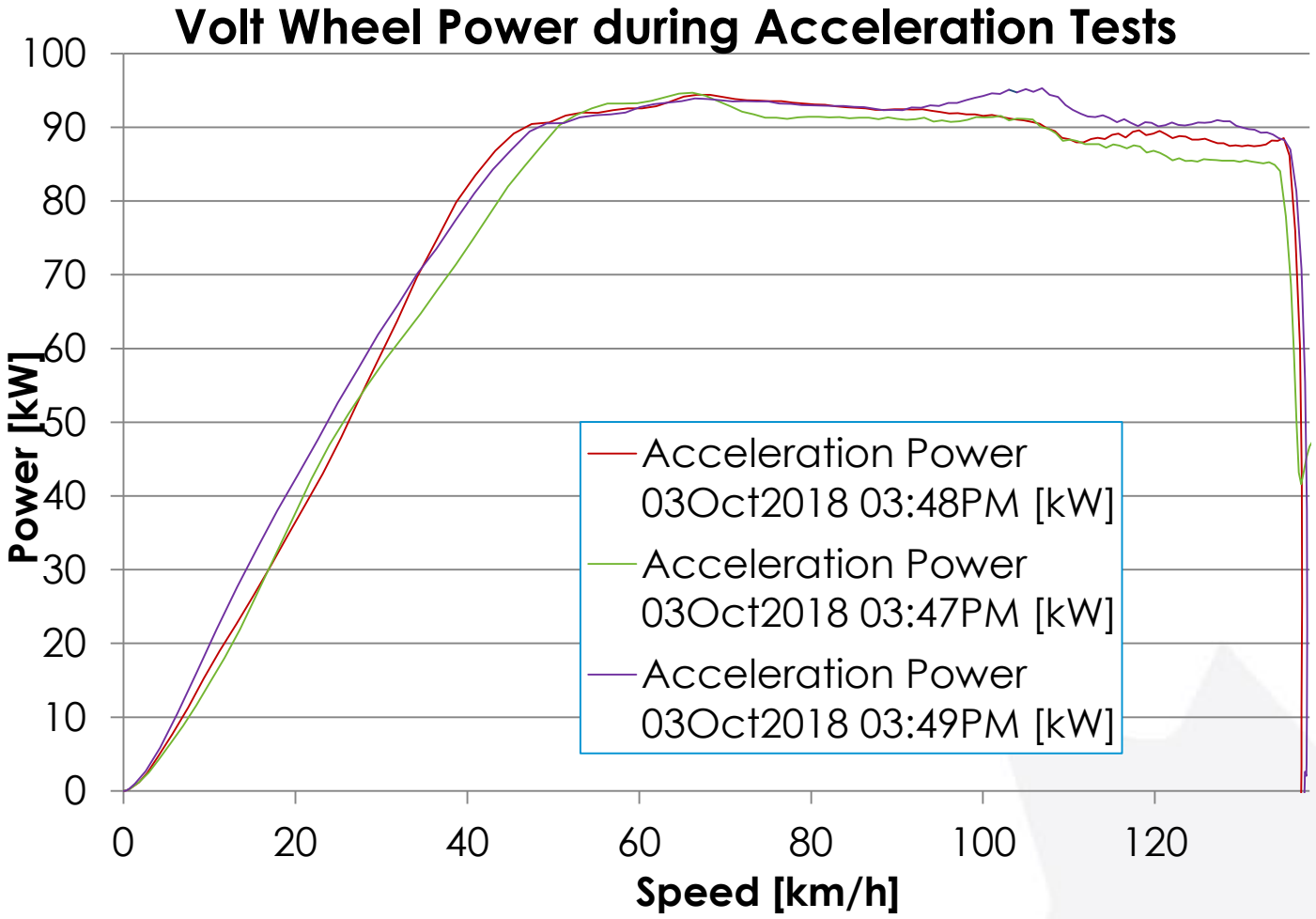
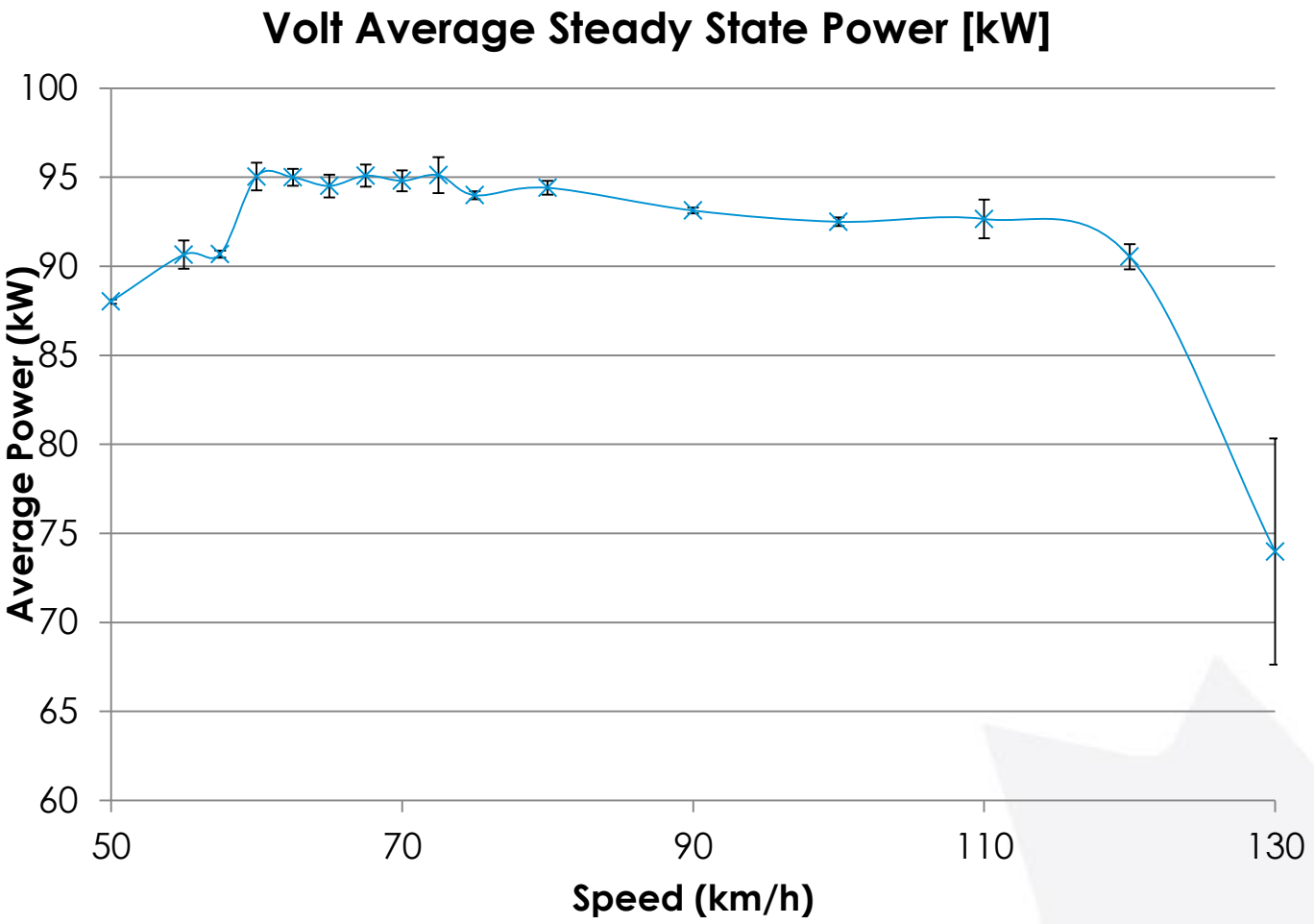


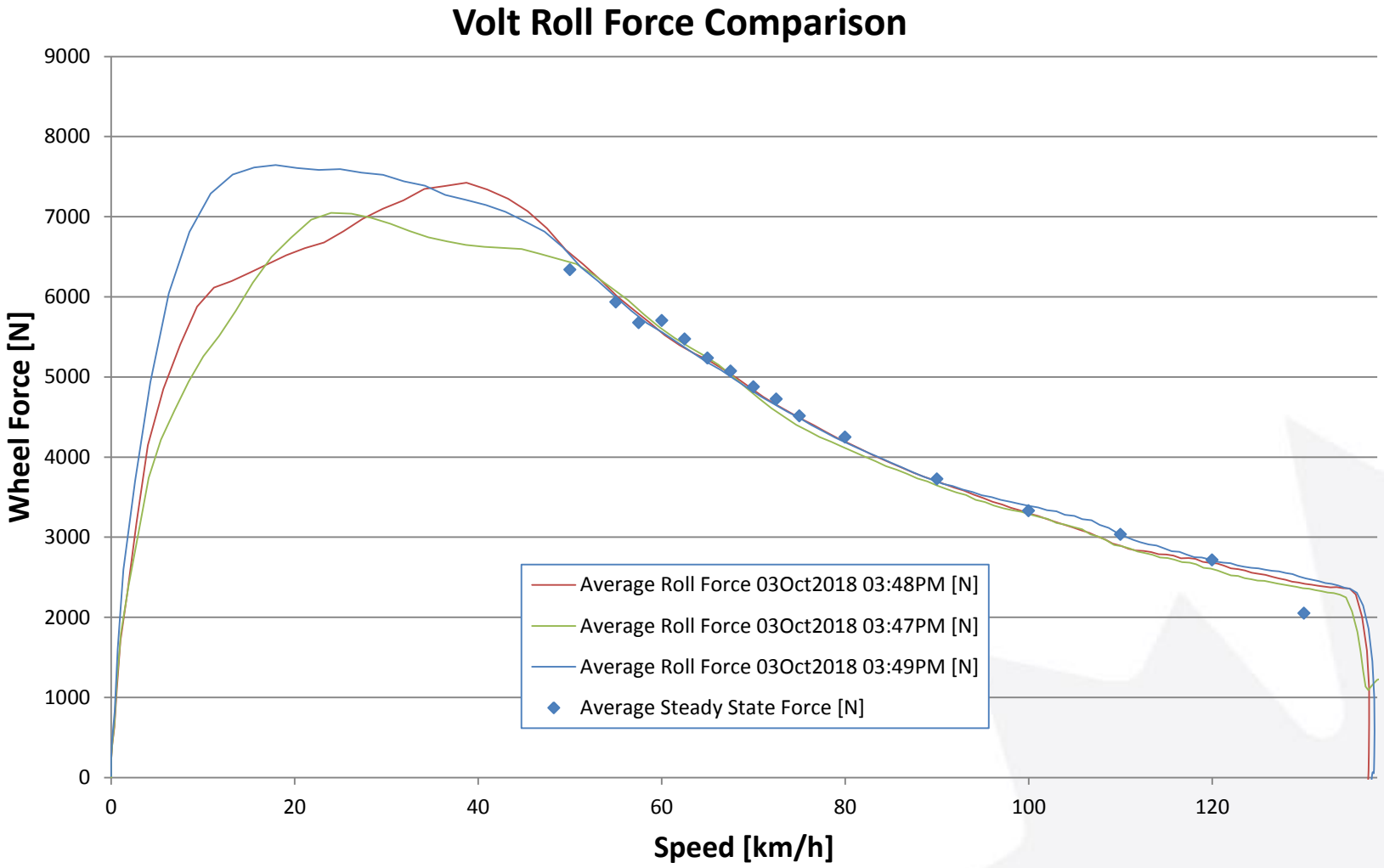
GM Volt Test Results – GTR Testing



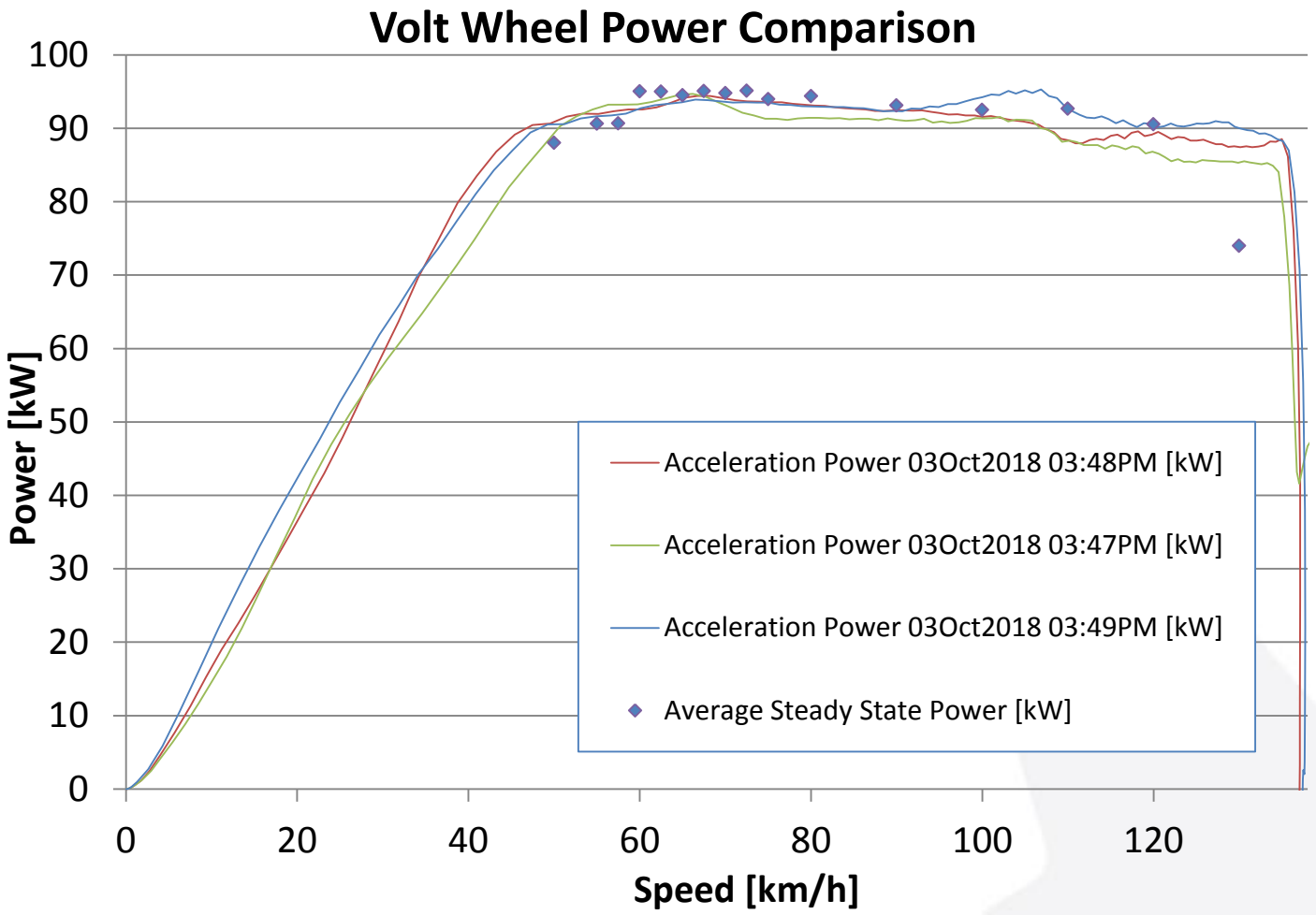
GM Volt Test Results – GTR Results

- Maximum Wheel Power from Dynamometer, Steady State 10s average:
  - P_{wh} = 95 kW (128 HP)
- GTR efficiency multiplier for the selected vehicle type (closest match):
  - Power split with planetary gearset, $\eta_{gearbox}$ = 0.93
- Maximum HEV System Power:
  - $P_{HEV\_system} = P_{wh} / \eta_{gearbox}$ = 102 kW (137 HP)

GM Volt Test Results – Accel vs Steady



GM Volt Test Results – Accel vs Steady



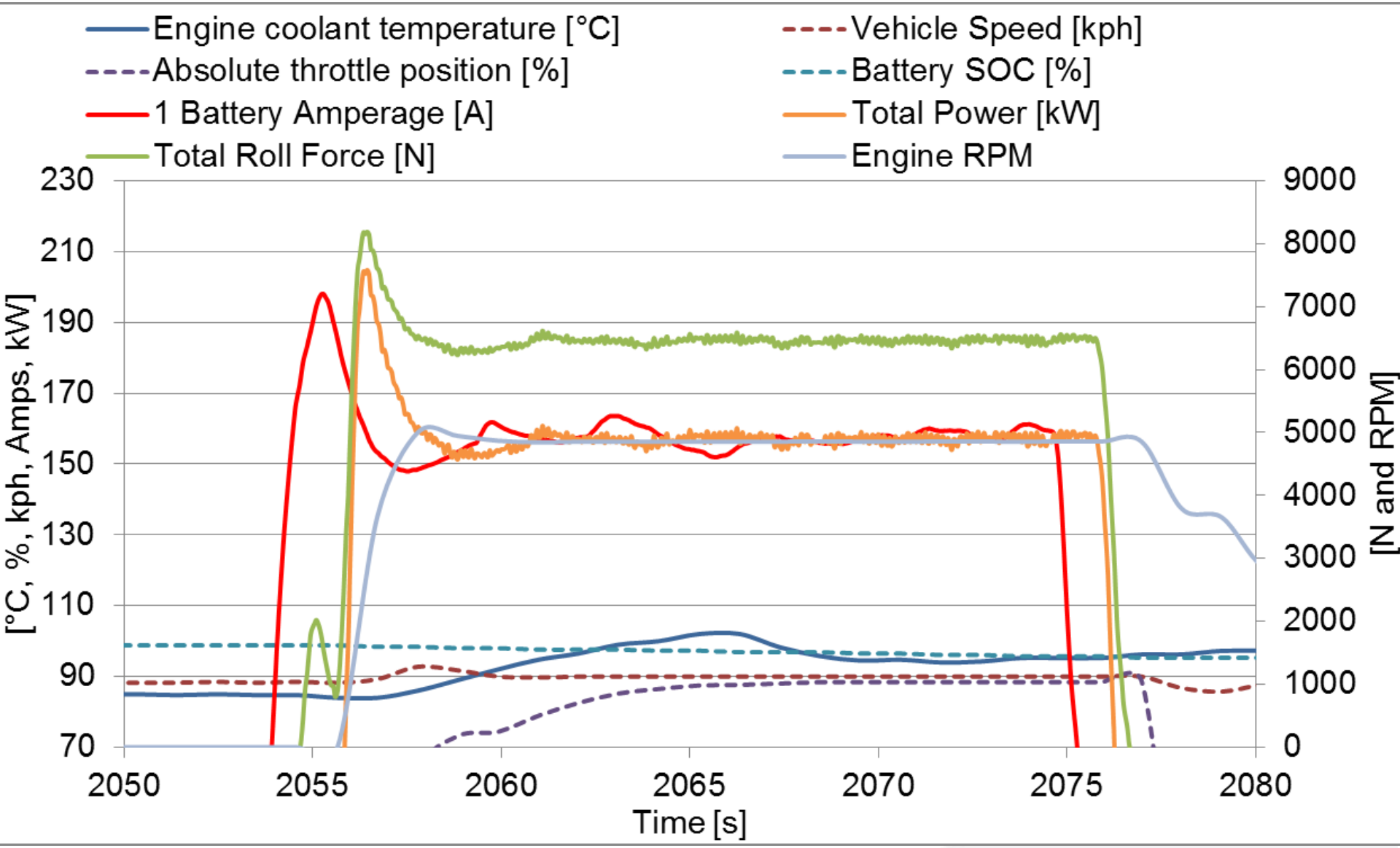
Discussion of Volt Test Results

- Gearbox multiplier does not take into account wheel rolling resistance and additional power loss that this causes, this would be an additional multiplier such that:

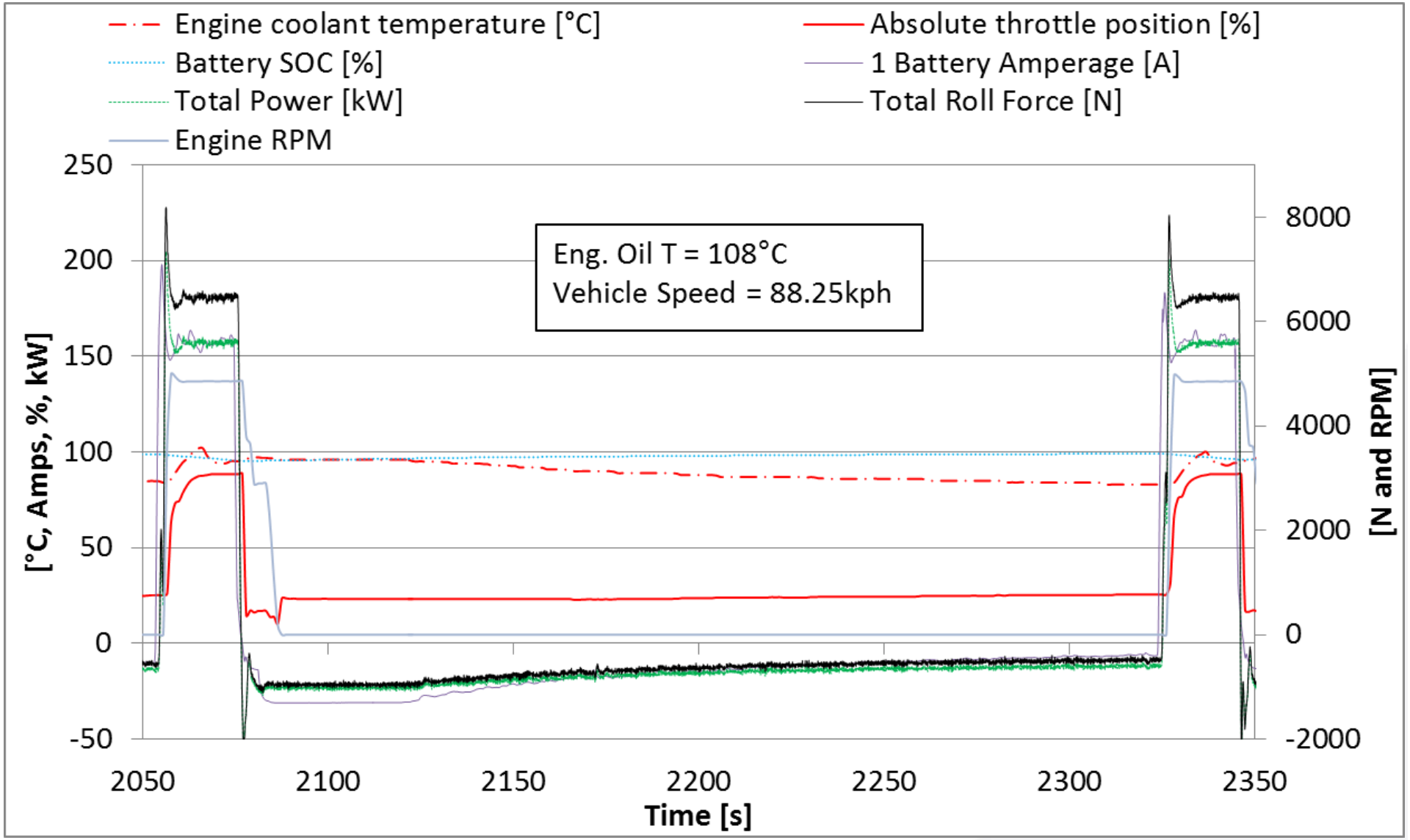
  $$P_{wh} = P_{HEV\_system} * \eta_{gearbox} * \eta_{tires}$$

  P_{HEV_system} is thus underreported by this method (i.e. vehicle is rated at 149 HP and test results using method TP2 showed only 137 HP, 8% lower)
- Power split HEV with planetary gearset type of powertrain was chosen for determination of $\eta_{gearbox}$ since vehicle has two planetary gearsets, however was run in full electric mode (engine did not turn on), there are only a few options for powertrains in the GTR Appendix
- Acceleration run results were very similar to steady-state results, could potentially be used to determine locations of interest for steady-state testing in order to speed up the method
- Power curve is very flat, difficult to determine exact peak power location of interest from coarse sampling run

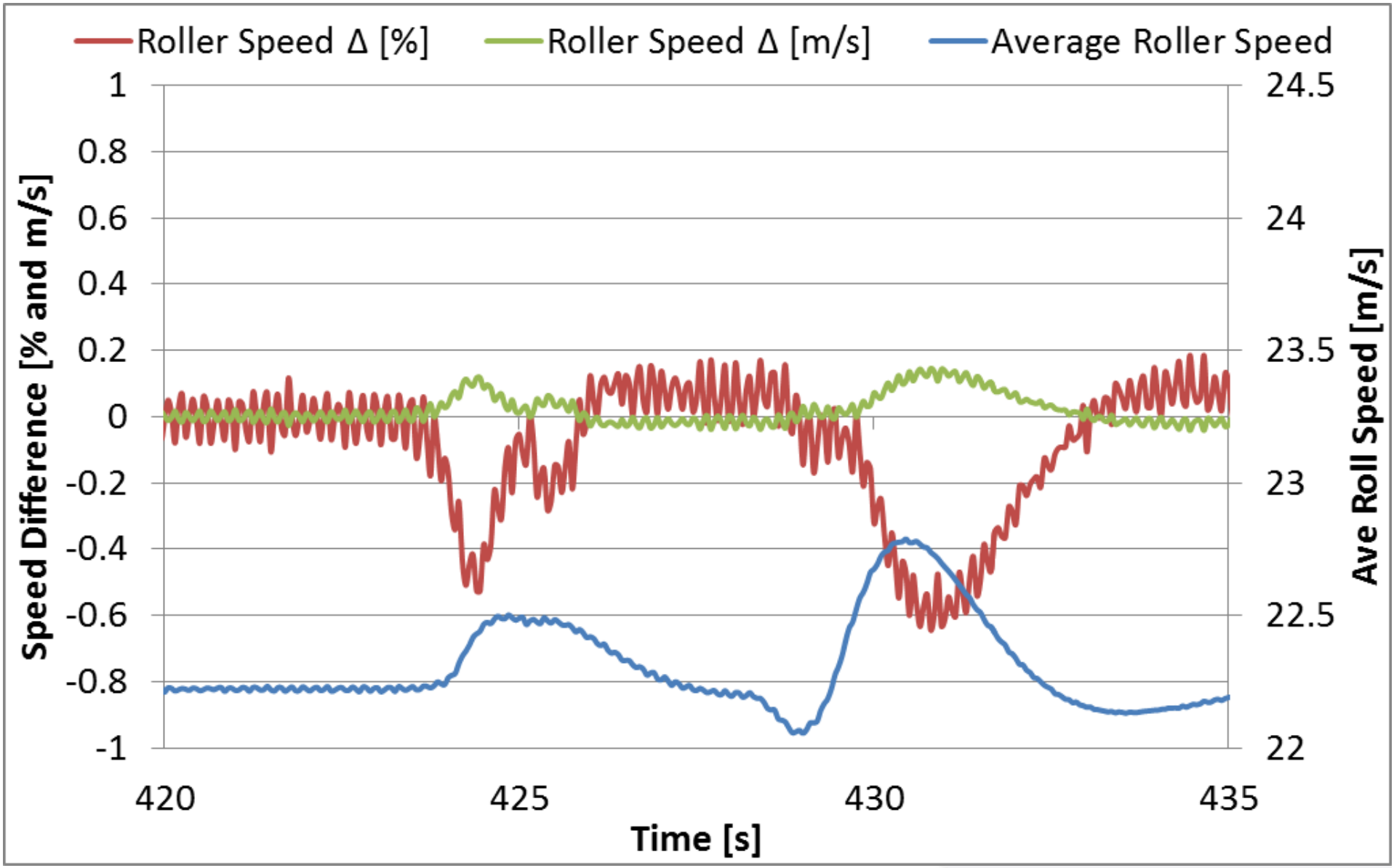
BMW 530e Test Results



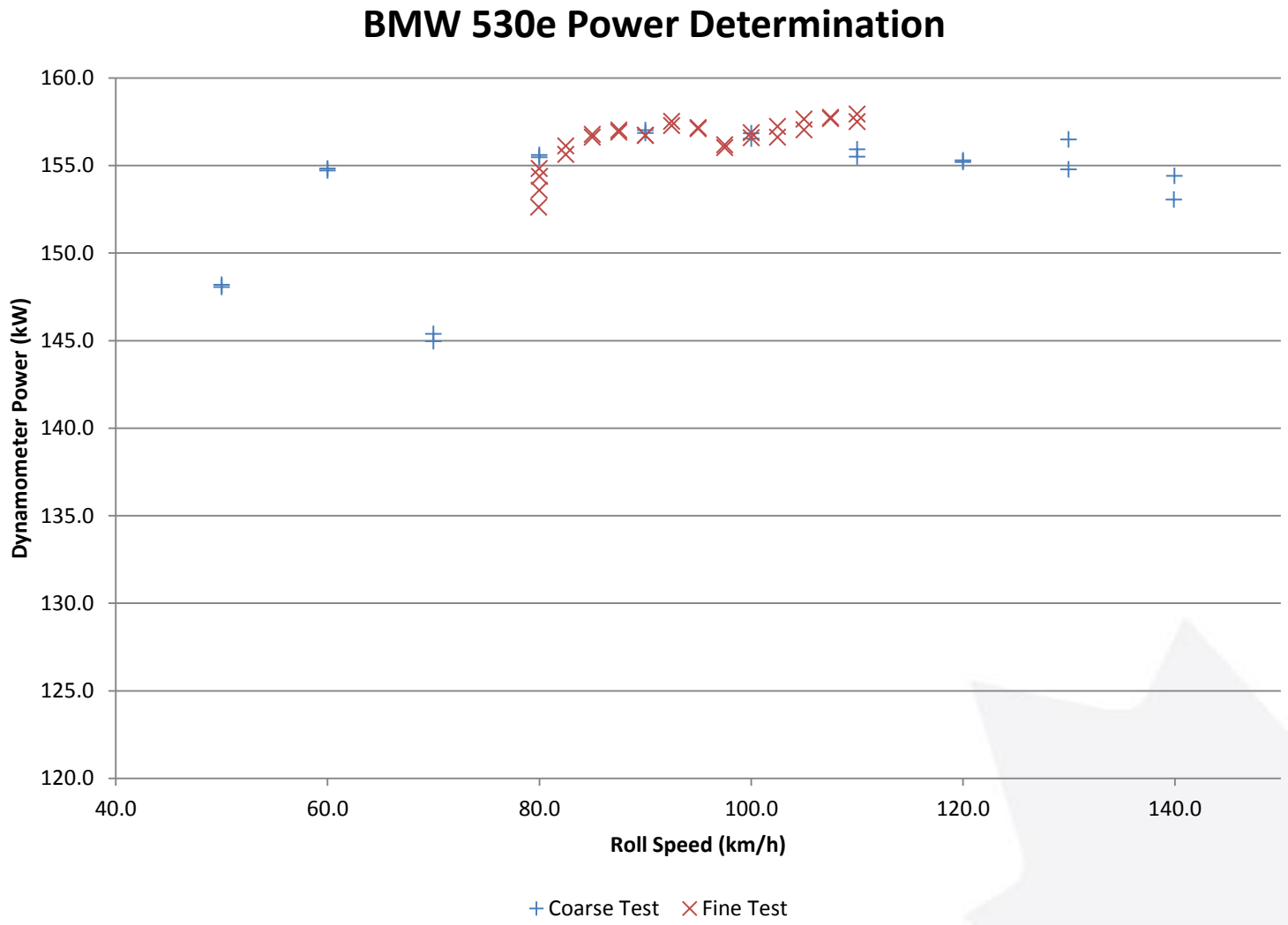
BMW 530e Test Results



BMW 530e Test Results



BMW 530e Test Results



BMW 530e Test Results – GTR Results

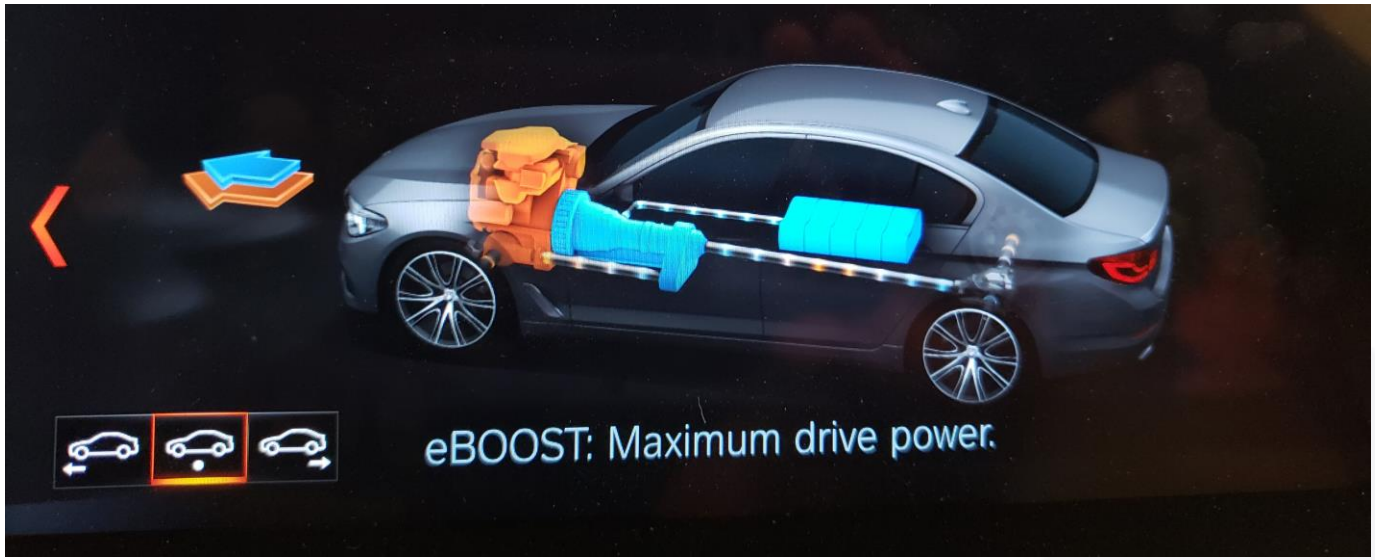
- Maximum Wheel Power from Dynamometer, Steady State 10s average:
  - P_{wh} = 157 kW (210 HP)
- GTR efficiency multiplier for the selected vehicle type (closest match):
  - AWD with Multi-speed automatic transmission, $\eta_{gearbox}$ = 0.96
- Maximum HEV System Power:
  - $P_{HEV\_system} = P_{wh} / \eta_{gearbox}$ = 164 kW (219 HP)

Discussion of BMW 530e Test Results

- Gearbox multiplier does not take into account wheel rolling resistance and additional power loss that this causes, this would be an additional multiplier such that:

$$P_{wh} = P_{HEV\_system} * \eta_{gearbox} * \eta_{tires}$$

P_{HEV_system} is thus underreported by this method (i.e. vehicle is rated at 248 HP and test results using method TP2 showed only 219 HP, 12% lower, potentially also due to AWD system losses)



Conclusions

- Coarse test dyno power from computer was used to determine position of a high resolution pass, several hours long procedure
  - Quick acceleration runs (3 minutes) may be able to replace this procedure
  - Manufacturer-specified test speed would eliminate the need for multiple test points entirely
- Is there an instruction about speed values for coarse test runs? 50-130 km/h was used with intervals of 10 km/h to start and 2.5 km/h for fine test
- Tie down instructions from the manufacturer would be ideal, side restraints were added but had some vehicle motion on dyno due to offset front and rear tow hooks vs suspension tie-down mounts
- In the draft document, paragraph of 6.8.2 states some considerations about temperature after prep and measurement “loops”, clarification could be added to this section

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