Validation Test Results at KATRI

- Power Determination of Hybrid Electric Vehicles -

Korea Transportation Safety Authority

Korea Automobile Testing and Research Institute

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Validation Program for testing method

System Power Determination

Validation testing plan by country

Country	Vehicle Models to be Tested	Laboratory Locations	Timelines	Notes
Canada (ECCC)	2016 Chevrolet Volt 2018 BMW 530e	River Road Facility	Anytime after spring 2018, with a few months notice	Already own Volts, 530e purchase approved and in process Potential additional funding if warranted
EU (JRC in Ispra/Europe with OICA)	To be agreed	JRC Dir C Energy, Transport and Climate, Ispra, Italy	2018 with a few months notice	Vehicle technology and type to be tested, to be agreed in advance Delivery of vehicles to be tested with appropriate monitoring system could be an ideal solution
Korea (KATRI)	2017 Hyundai Ioniq Hybrid	Korea Automobile Testing and Research Institute	2018 (March to April)	
U.S. (EPA)	2013 Malibu Hybrid 2013 Chevrolet Volt	U.S. National Vehicle and Fuels Emissions Laboratory	Anytime after spring 2018, with a few months notice	
Japan (JARI)	2015 Toyota Yaris 2015 Honda Fit 2016 Mitsubishi outlander PHEV			Already done, supporting with test report

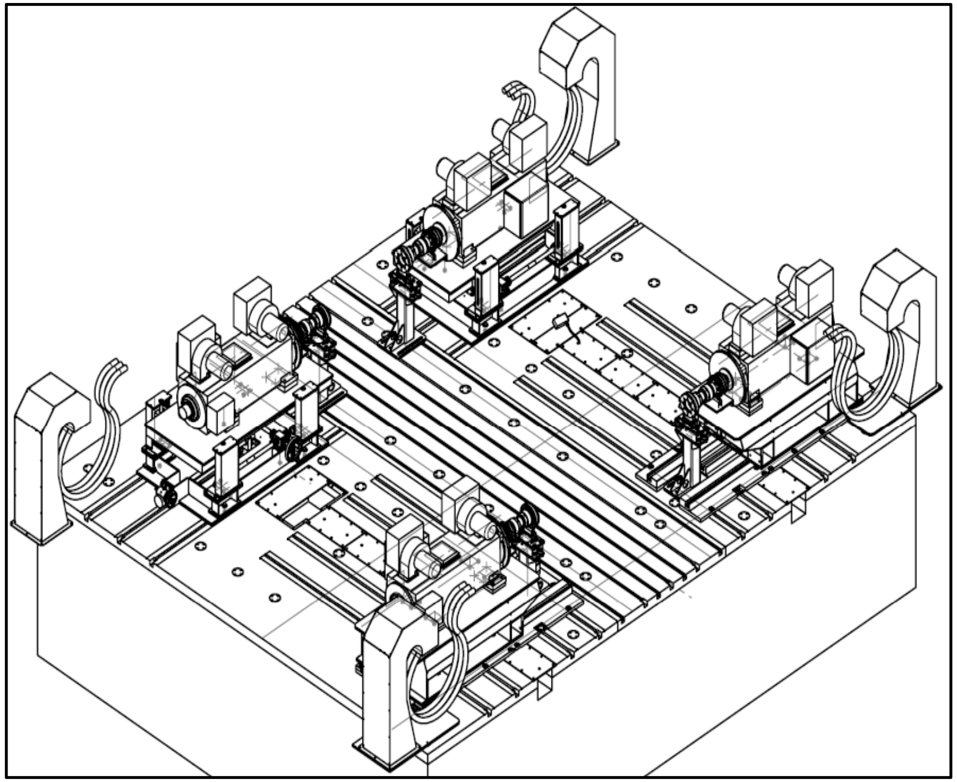
Specification of powertrain for test vehicle

❖ **Manufacturer: Hyundai Motor Company**

Items / Test Vehicle	Power			Gearbox system	Accumulated mileage [km]
	ICE [kW/min^{-1}]	E-Motor [kW/min^{-1}]	REESS system [kWh]		
IONIQ hybrid (P2, NOVC-HEV)	77.3 /5,700 (1,580cm^3)	32 /1800 (PMSM)	1.56 (240V, 6.5Ah)	DCT(6)	3,038

Test instrument_dynamometer system

Hub dynamometer

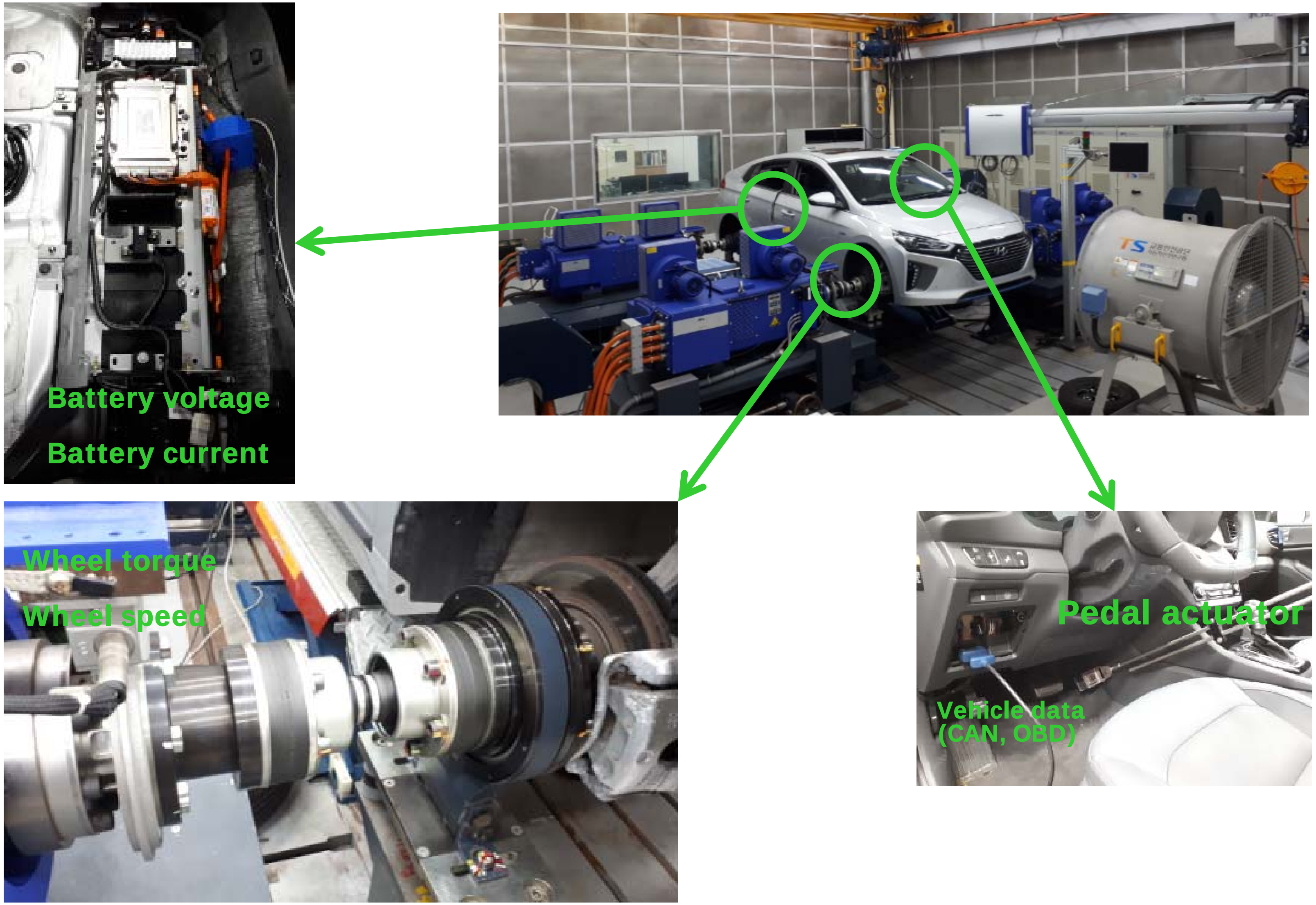


- **Dynamometer spec.**

- Max power : 290 kW @1100 ~ 3000 rpm
- Max torque : 2500 Nm @ ~ 1100 rpm
  (40% overload : 3500 Nm)
- Max speed : 3000 rpm
- Supporting weight : 750 kg in each wheel
- Inertia : 0.87 kgm^2
- Wheel base : 1.8 ~ 3.8 m
- Thread : 1.2 ~ 2.2 m

- **Actuator for acceleration pedal**

Vehicle setup



Measurement

❖ Measurement items and accuracy according to ISO 20762

Item	Units	Accuracy	Remarks	This test
Engine speed	min^{-1}	±0.5 %	-	**CAN**
Intake manifold pressure	Pa	±50 Pa	Intake manifold pressure means inlet depression in ISO 1585	**OBD**
Atmospheric pressure	Pa	±0.5 kPa, with a measurement frequency of at least 0.1 Hz		**O.K.**
Humidity				**-**
Electrical voltage	V	±0.3 % FSD or ±1 % of reading	Whichever is greater. Resolution 0.1 V	**O.K.** **CAN**
Electrical current	A	±0.3 % FSD or ±1 % of reading	Whichever is greater. Current integration frequency 20 Hz or more. Resolution 0.1 V	**O.K.** **CAN**
Electrical energy	Wh	±1 %	Resolution 0.001 kWh. Equipment: static meter for active energy. AC watt-hour meter, Class I according to IEC 62053-21 or equivalent	**O.K.**
Room temperature	K	±1 ℃, with a measurement frequency of at least 0.1 Hz		**O.K.**
Time	s	±10 ms; min. precision and resolution: 10 ms		**O.K.**
Wheel speed	s^{-1}	±0.05 s^{-1} or ±1 %, whichever is greater		**O.K.**
Wheel torque	Nm	±6 Nm or ±0.5 % of the maximum measured total torque, whichever is greater, for the whole vehicle, with a measurement frequency of at least 10 Hz		**O.K.**

❖ Measurement frequency : 100 Hz (ISO 20762: not less than 10 Hz)

❖ Time for full load (Acc. 100％) : ~20 s (ISO 20762: at least 10 s)

Determination of vehicle speed for the test

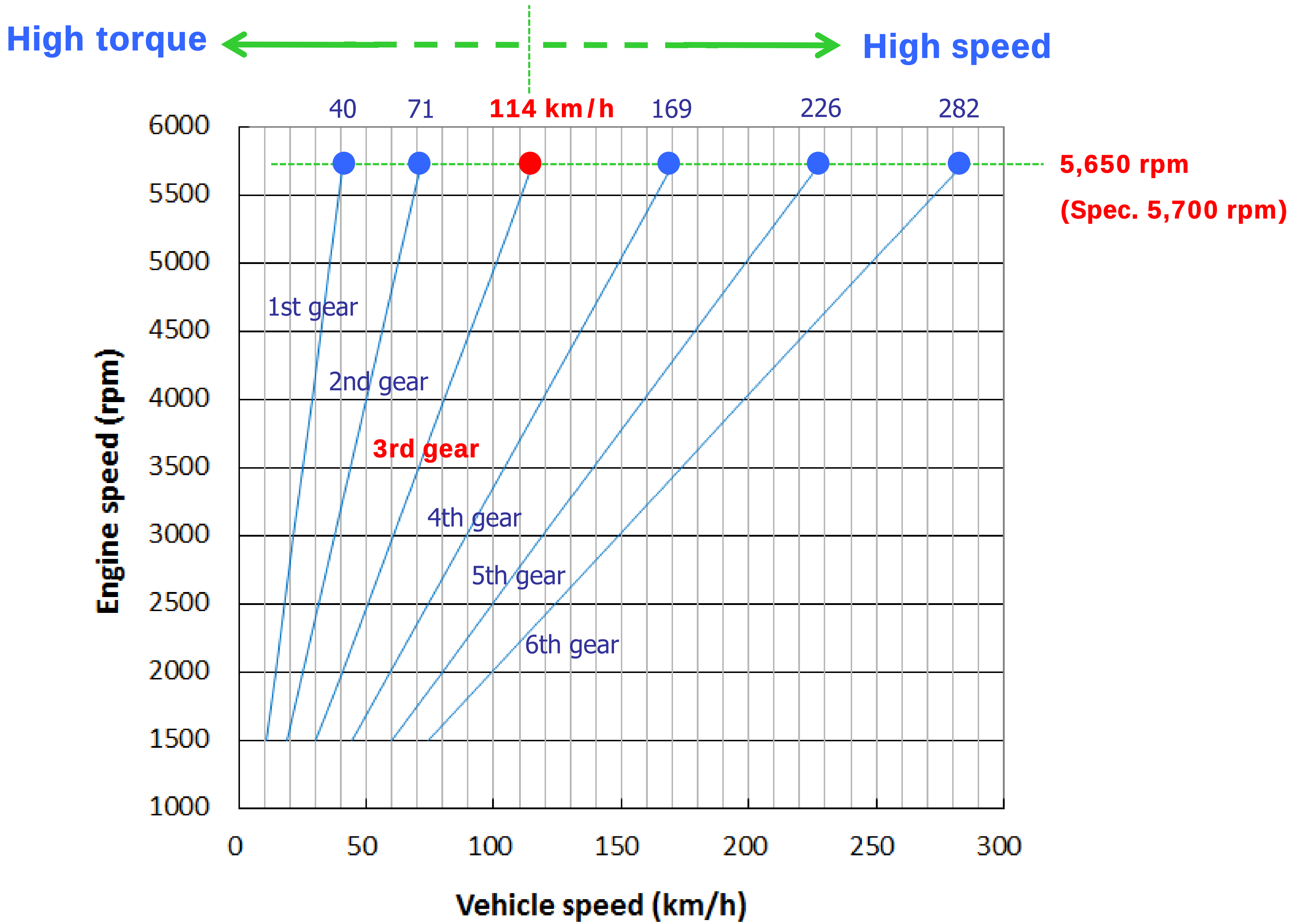
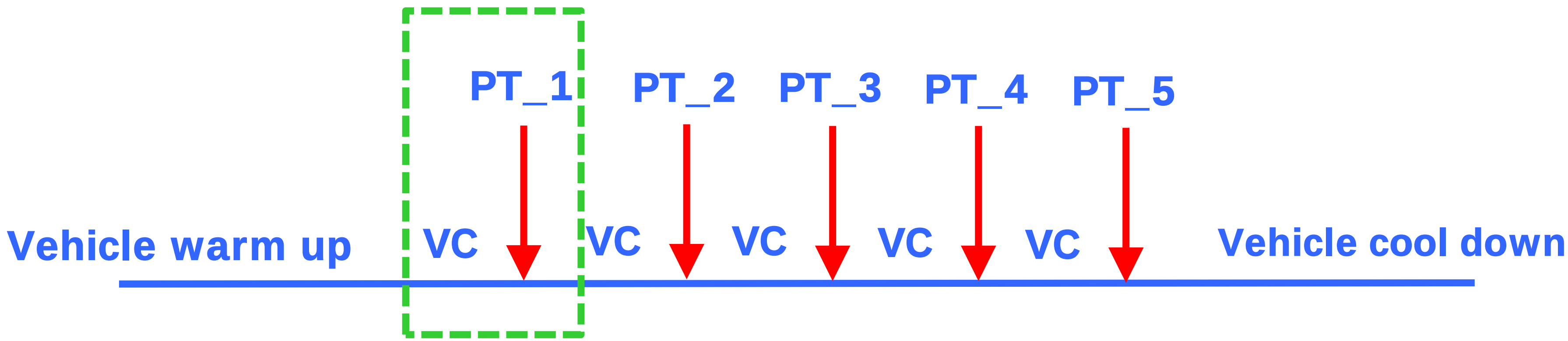


Diagram for test procedure



- **VC : Vehicle Conditioning**
  - **VC1 : 20 min at 60 km/h (~115 min)***
  - **VC2 : 10 min at 70 km/h (~65 min) ***

  ***Testing time**

- **PT : Power Test**

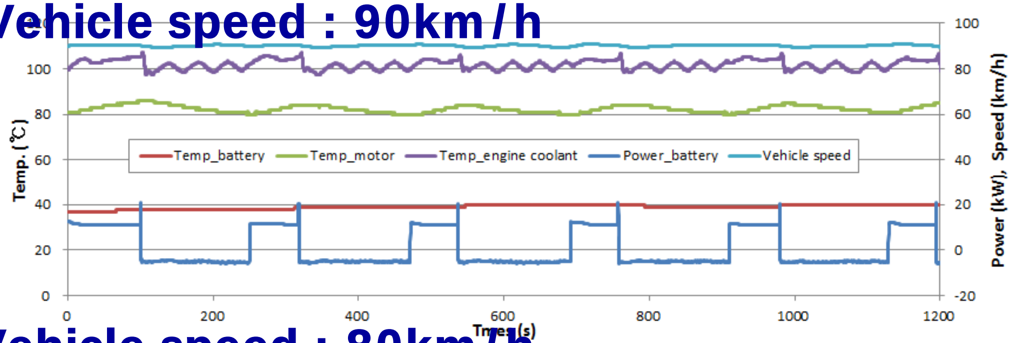
- **TP : Test Procedure**
  - **TP1* : Test procedure option 1**
  - **TP2** : Test procedure option 2**

  ***TP1 : Test procedure via measured REESS power and determined ICE power**

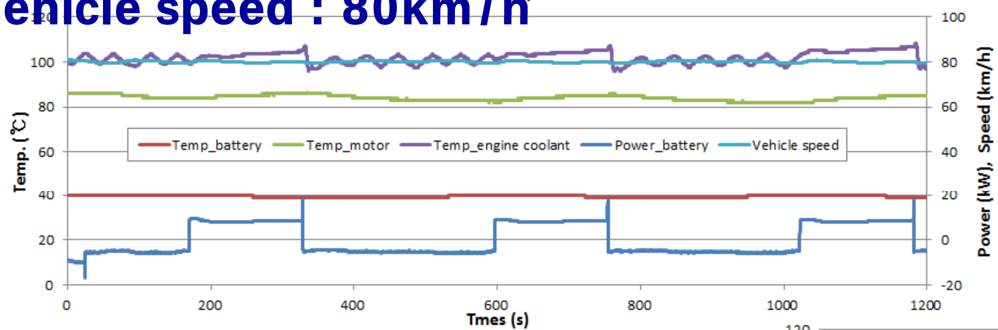
  ****TP2 : Test procedure via torque and speed measurement**

Vehicle conditioning and REESS adjustment

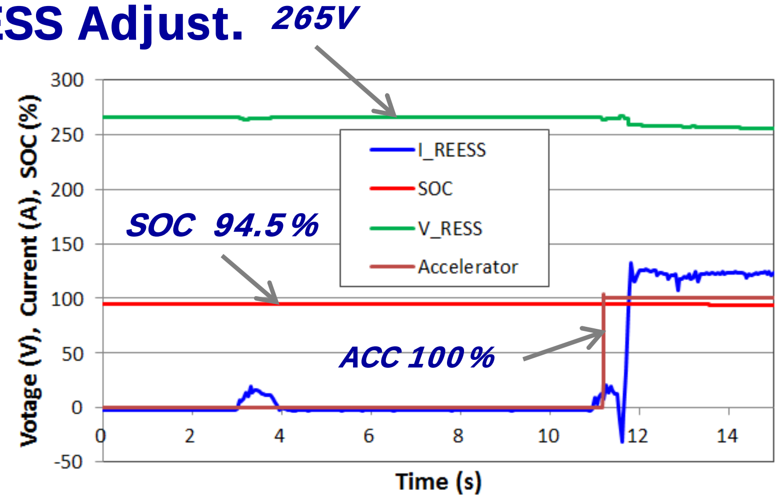
Vehicle speed : 90km/h



Vehicle speed : 80km/h

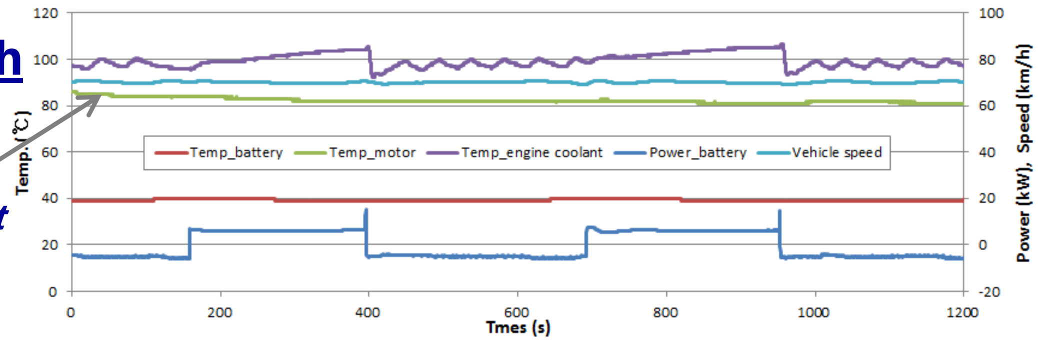


REESS Adjust.

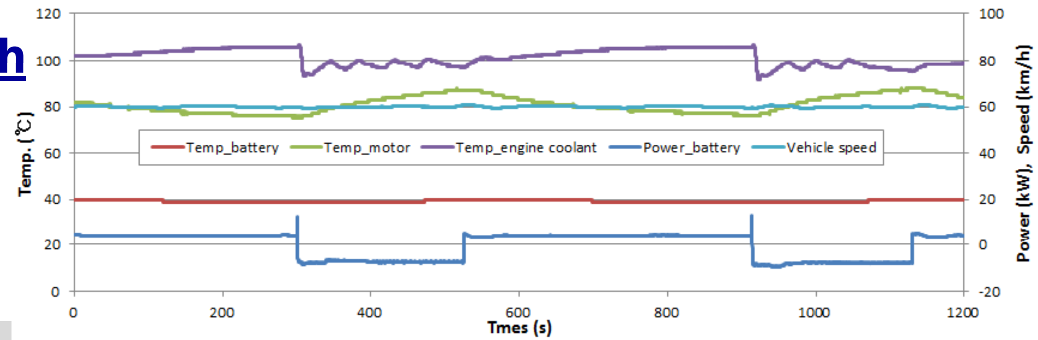


- ✓ **Vehicle speed : 70km/h**

Motor temp is nearly constant

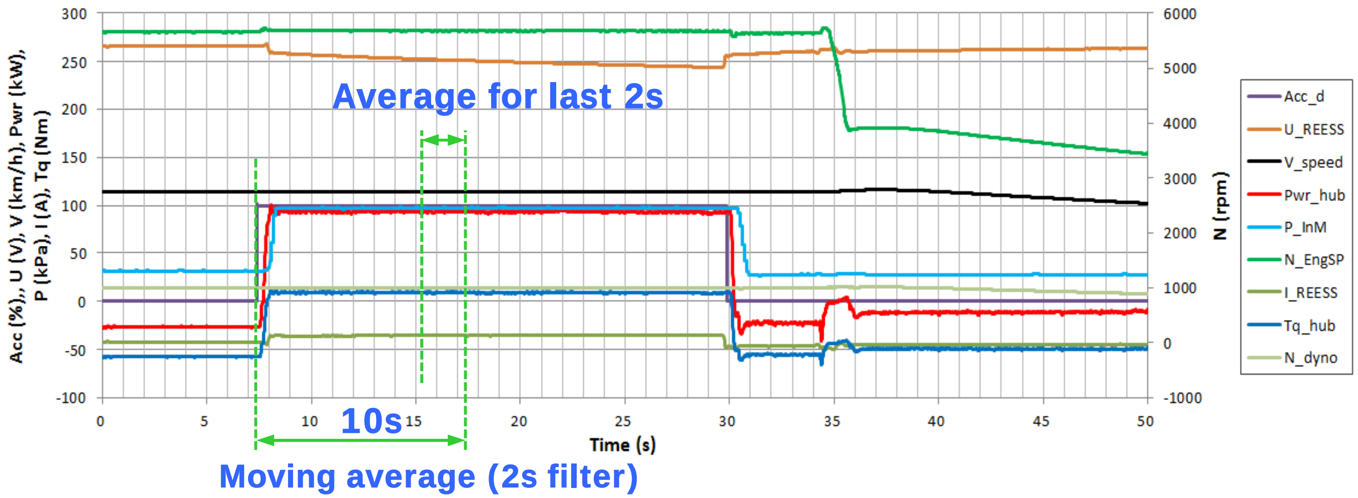


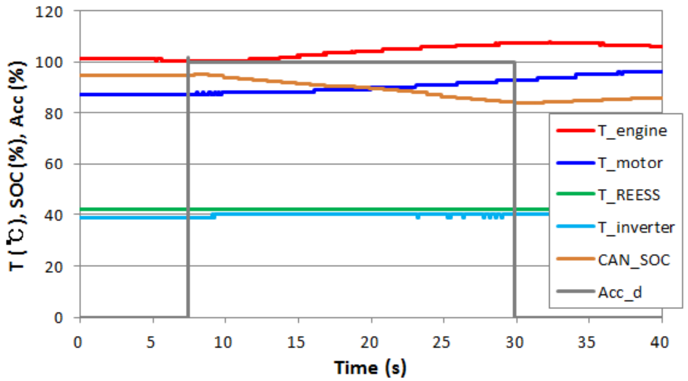
- ✓ **Vehicle speed : 60km/h**



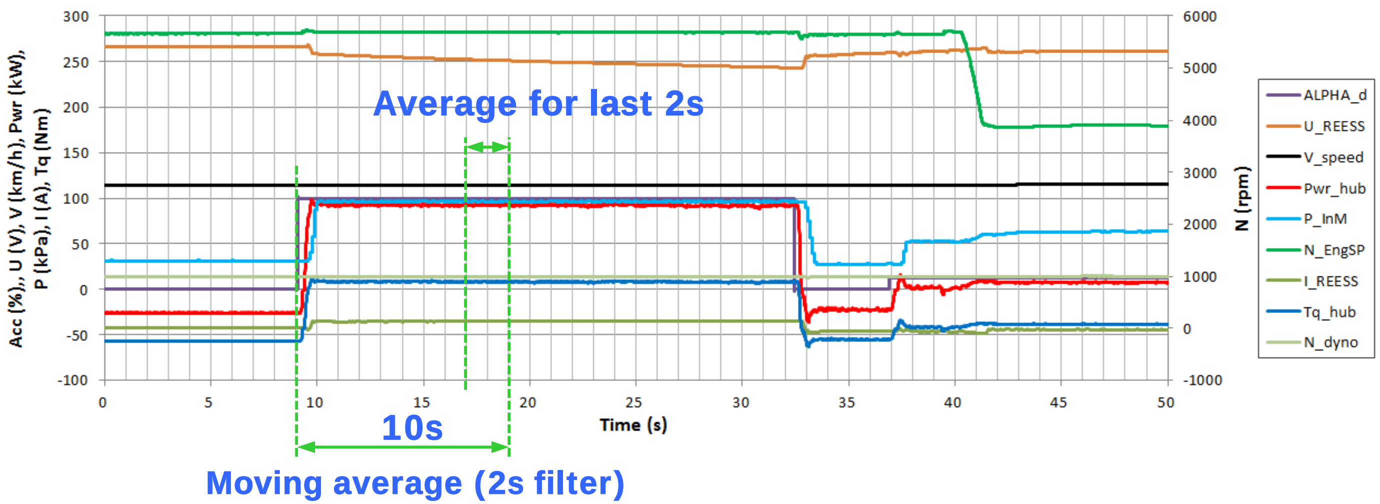
System power test

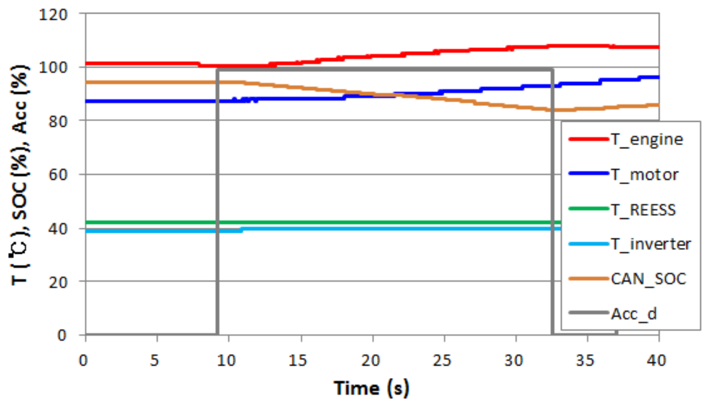
VC1 : 20 min at 60 km/h **Power test @ 114km/h**





VC2 : 10 min at 70 km/h **Power test @ 114km/h**



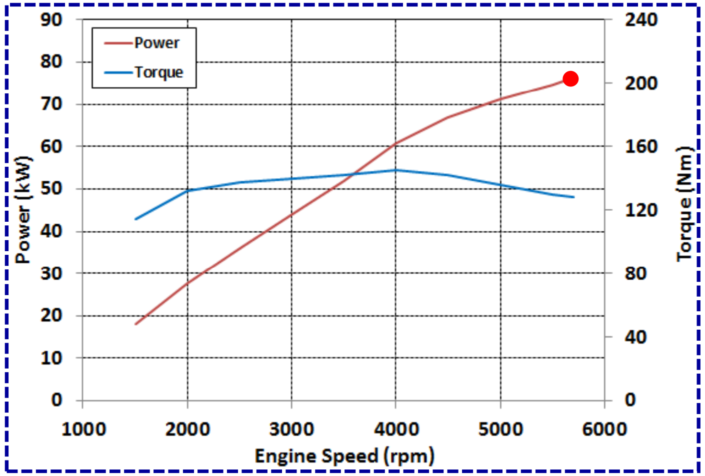


Calculation for TP1

"Sustained power"

- **ICE power, $P_{ICE(corr)}$: 76.5 [kW]**

[From engine dyno test]



- **Converted REESS power, $P_{REESS(con)}$**

$$P_{REESS(con)} = [U_{REESS} \times I_{REESS} / 1000 - P_{DCDC} - P_{aux}] \times K$$

$$= [\ \underline{31.4} - 1.0 - 0\ ] \times \underline{0.88}$$

$$= \mathbf{26.7\ [kW]}$$

[From motor dyno test]

K = [Output power of motor] /
[Input power of inverter]
= 31.97 / 36.34
= 0.88

- **HEV system power, P_{HEV}**

$$P_{HEV} = P_{ICE} + P_{REESS(con)}$$

$$= 76.5 + 26.7$$

$$= \mathbf{103.2\ [kW]}$$

Calculation for TP2

"Sustained power"

- **HEV system power at the wheels, P_{HEVw} : 93.9 [kW]**
- **HEV system power, P_{HEV}**

$$P_{HEV} = [\, P_{HEVw} / \eta_{gb} \,]$$
$$= [\, 93.9 / 0.97 \,]$$
$$= \mathbf{96.8\ [kW]}$$

Need for correction at reference atmospheric and temperature conditions

Gearbox system efficiency factors,
η_{gb} : 0.97
(dual-clutch automatic)

- **ICE power, P_{ICE}**

$$P_{ICE} = P_{HEV} - P_{REESS(con)}$$
$$= 96.8 - 26.7$$
$$= \mathbf{70.1\ [kW]}$$

- **Corrected ICE power, $P_{ICE(corr)}$**

$$P_{ICE(corr)} = P_{ICE} \times f$$
$$= 70.1 \times 0.986$$
$$= \mathbf{69.1\ [kW]}$$

ICE power correction factors,
f : 0.986

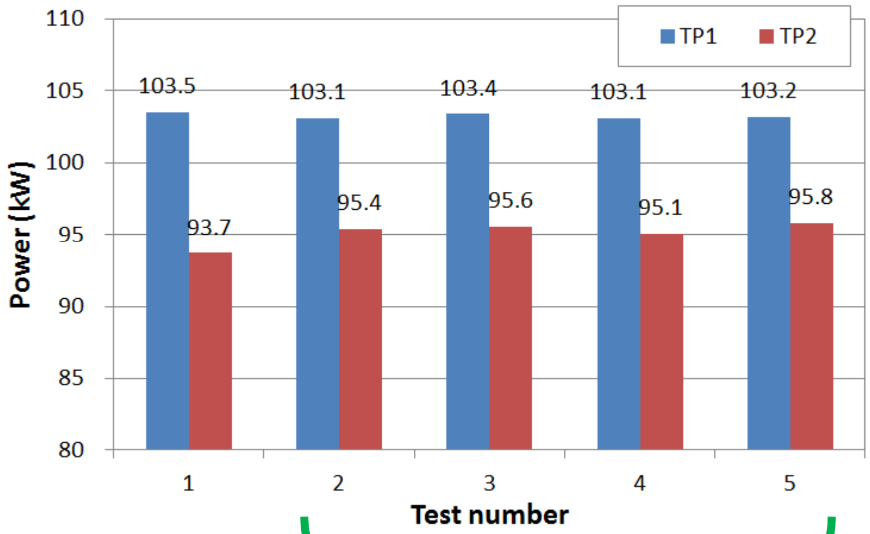
- **Corrected HEV system power, $P_{HEV(corr)}$**

$$P_{HEV(corr)} = P_{ICE(corr)} + P_{REESS(con)}$$
$$= 69.1 + 26.7$$
$$= \mathbf{95.8\ [kW]}$$

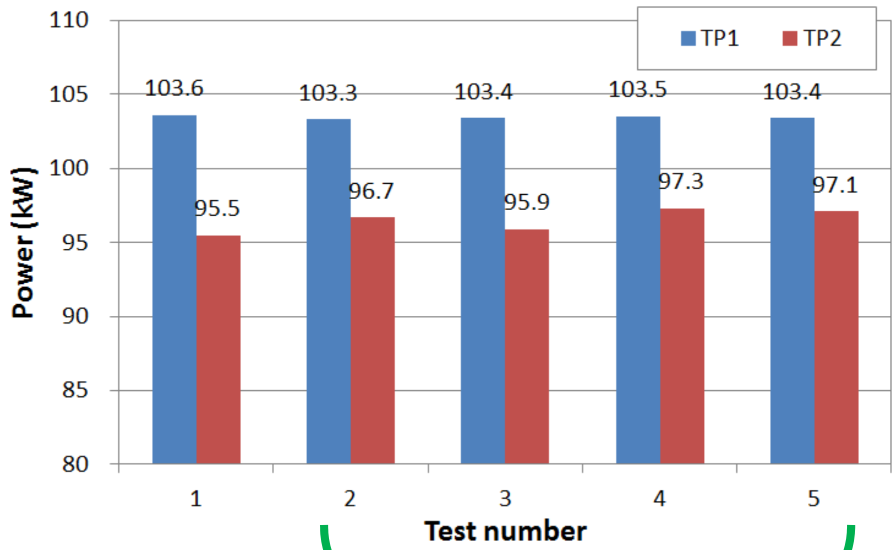
Test results (1)

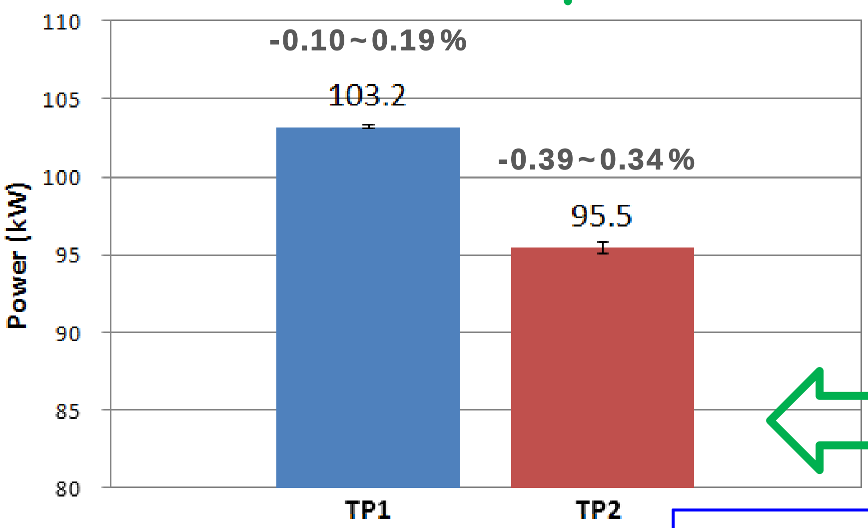
VC1 : 20 min at 60 km/h   Power test @ 114km/h

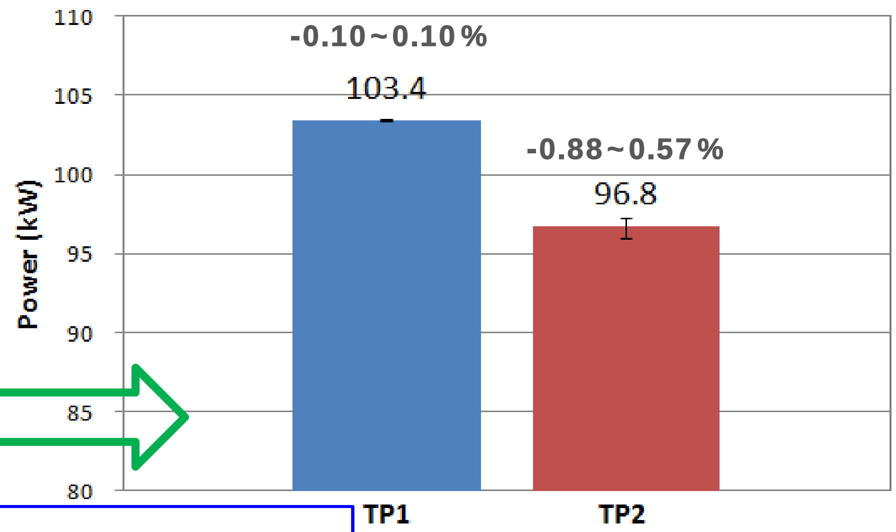
Sustained Power



Peak Power





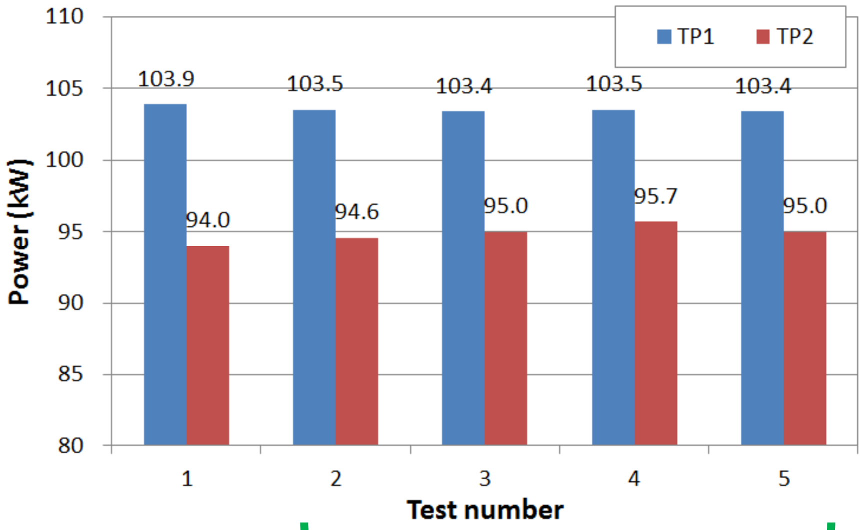


TP1 : 0.19%, TP2 : 1.34%

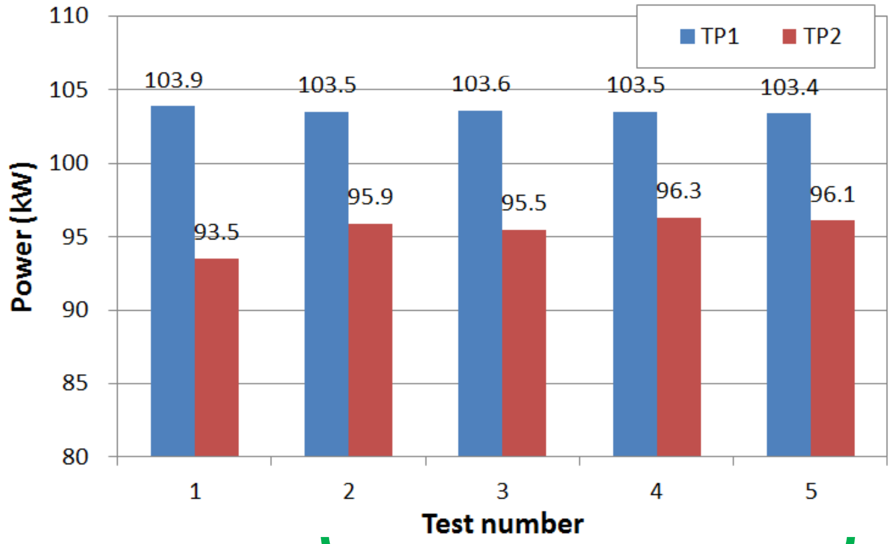
Test results (2)

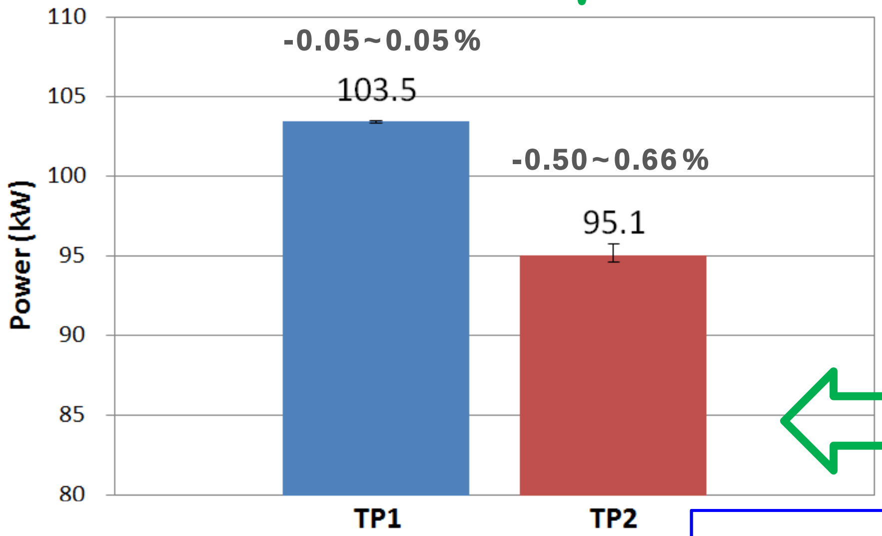
VC2 : 10 min at 70 km/h   Power test @ 114km/h

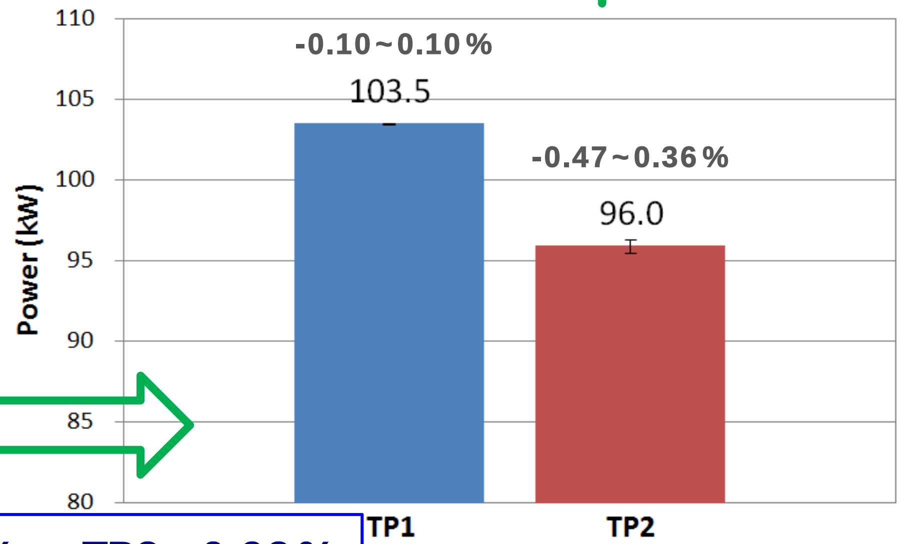
Sustained Power



Peak Power







TP1 : 0.05%, TP2 : 0.92%

Korea proposal on the GTR draft

1. To add a hub dynamometer option to the test instrumentation

SAE J2908

4.3 Hub Dynamometer

A hub dynamometer is suitable for all testing covered in this document. Because of low rotating inertia, special care needs to be taken to avoid oscillations, overshoots, or other transient problems that may interfere with measurement or could damage the test and measurement hardware or vehicle components. A hub dynamometer connects to the vehicle's hub (usually with the brake assembly remaining intact). Absorption mode is required for all tests (Sections 7, 8, 9, and 10), and motoring capability is required for the Peak Electric Regenerative Braking Power Test (Section 10).

Vehicles tested on a hub dynamometer shall be operated with the same vehicle control used in normal on-road driving. This may require speed synchronization of all axles and proper vehicle posture (among other vehicle testing properties).

4.4 Chassis Dynamometer

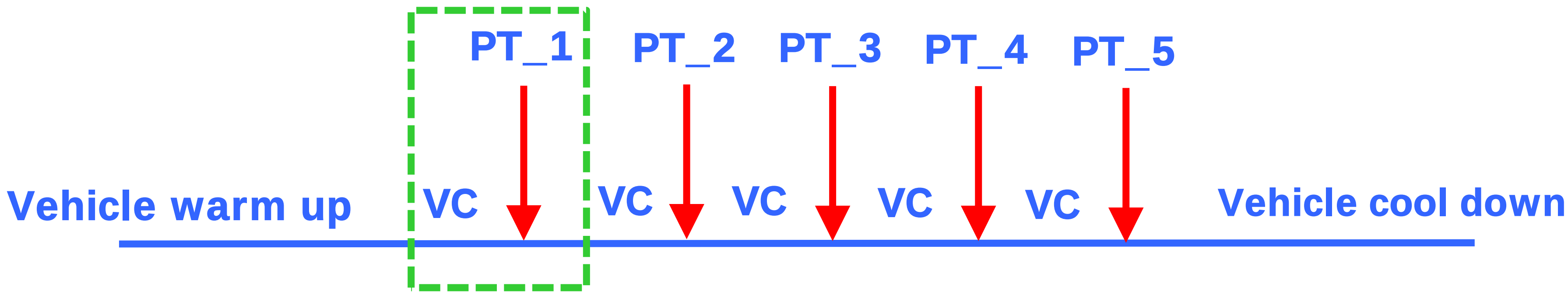
A chassis dynamometer is suitable for all testing covered in this document, provided instrumentation is added to the vehicle that accurately measures all powertrain propulsion power (torque and speed) at either the axles or the wheels. Absorption mode is required for all tests (Section 7, 8, 9, and 10); motoring capability is required for only the Peak Electric Regenerative Braking Power Test (Section 10).

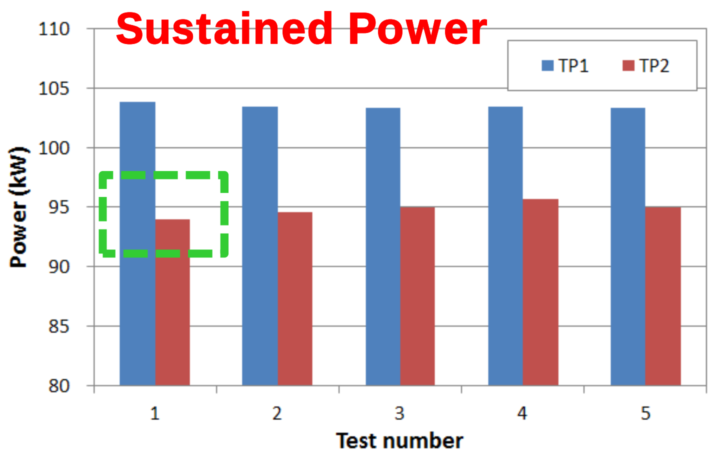
4.5 Axle/Wheel Torque Sensors

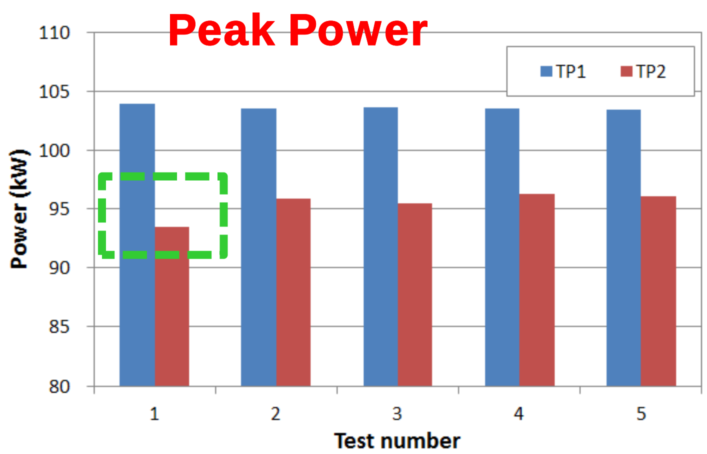
When using a chassis dynamometer, total powertrain power (torque and speed) can be measured from axle torque sensors or torque sensor assemblies that measure torque between the wheel hub and the tire. Direct measurement of wheel (axle) speeds are necessary, as chassis dynamometer speed will not be accurate because of tire slip.

Korea proposal on the GTR draft

2. To exclude the 1st power test result in calculation of system power







3. Korea prefer TP2 and Sustained power for determination of HEV system power

Thank you for the attention

Q&A

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