SAE J2908 Vehicle System Power Rating

SAE J2908-2023

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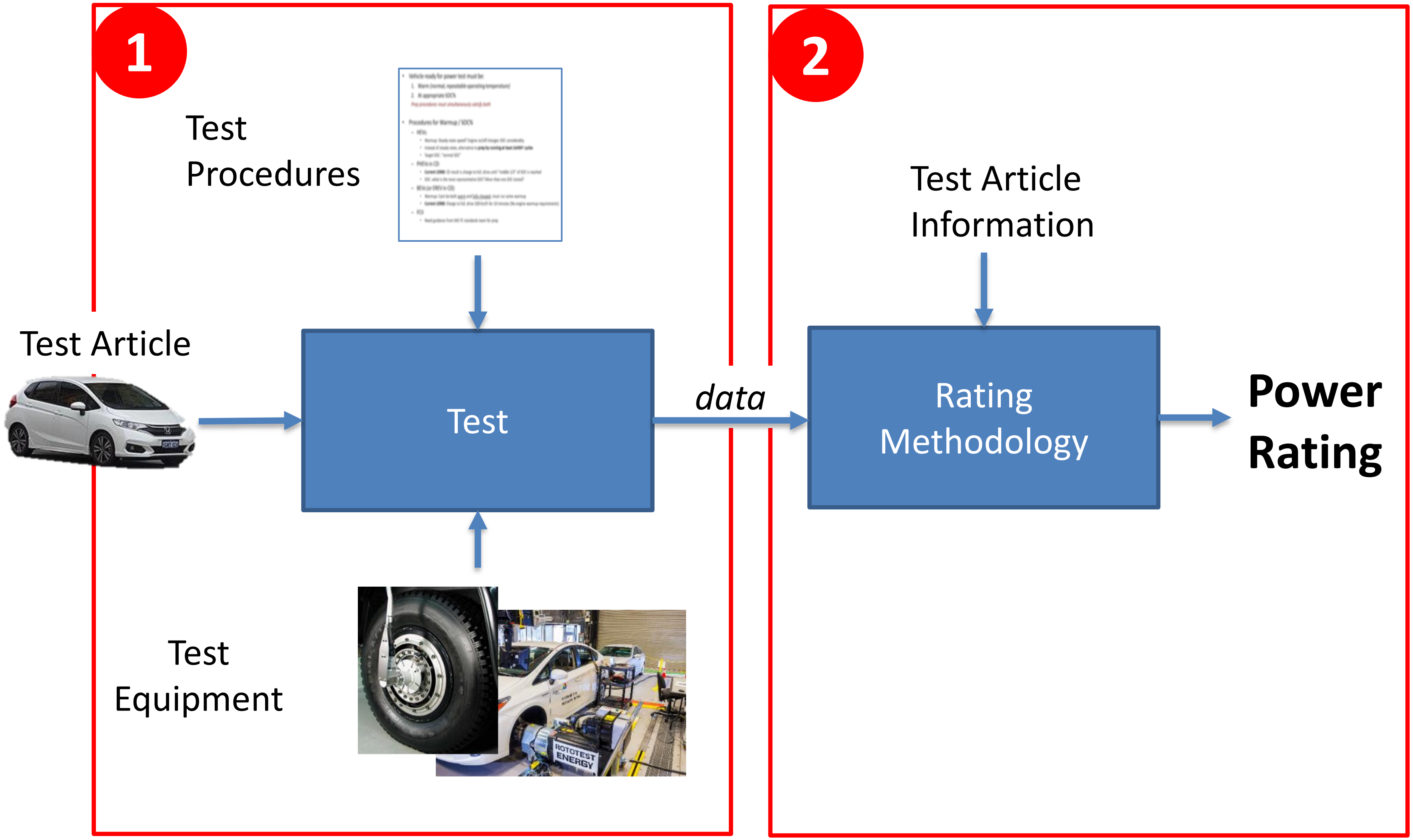
SAE J2908 History

J2907 – <u>Motor</u> Subsystem Rating (motor + inverter)

J2908 – Vehicle <u>System</u> Rating

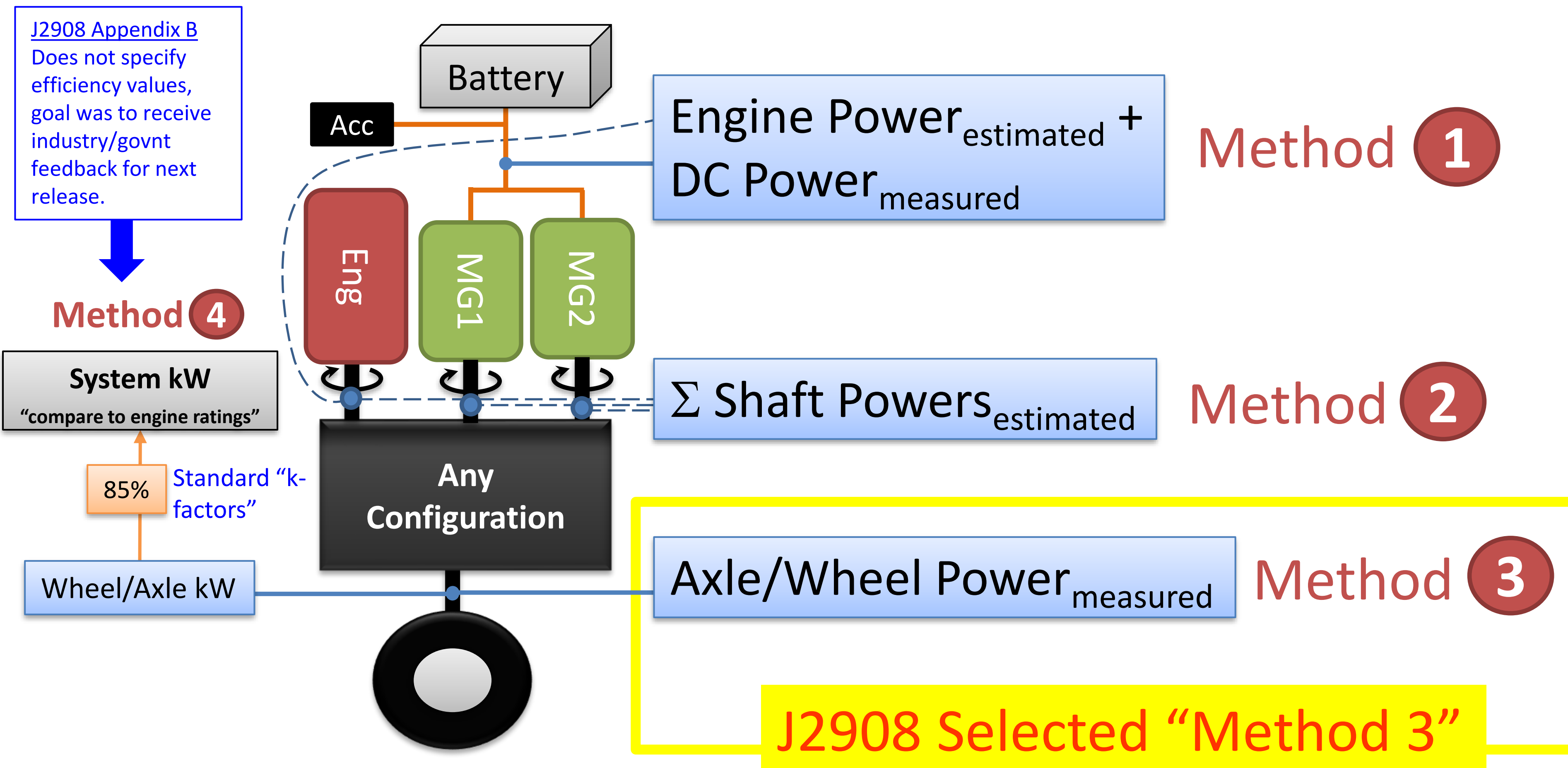
- J2907/J2908 originally given SAE "J-doc" numbers more than 15 years ago, due to lack of progress, committee was tabled
- 2013: J2907 restarted (published in 2017)
- 2014: **J2908 restarted**
- July 2014: Argonne exploratory **chassis dyno** testing
- Summer 2015: rented **hub dyno** for testing
- **→ J2908 published Sept 2017**
- J2908 reopened 2020 (hybrid pickup truck HP war?)
- **→ J2908 revision published Jan 2023**

J2908 at a 40,000-foot view



Fundamental options explored in J2908-2017

Never stopped asking question: What is **System Power**?



✓ 3rd party validation
✓ Valid for all xEV

J2908 Starts with a **Test**

Flexibility to use either dyno equipment option

Hub Dyno

or

Chassis Dyno

or

Wheel or axle torque sensor needed
for power direct power measurements

Prep Methods

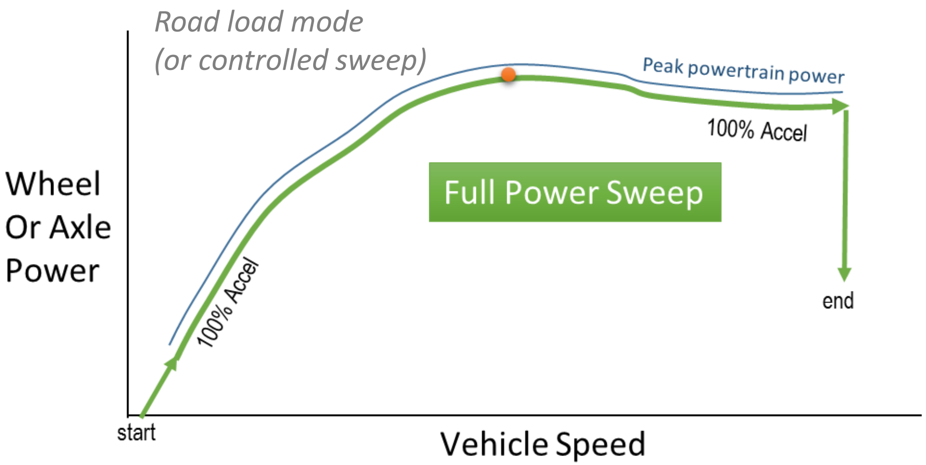
- Vehicle ready for test must be:
  1. Warm *(normal, repeatable operating temperature)*
  2. At appropriate SOC%

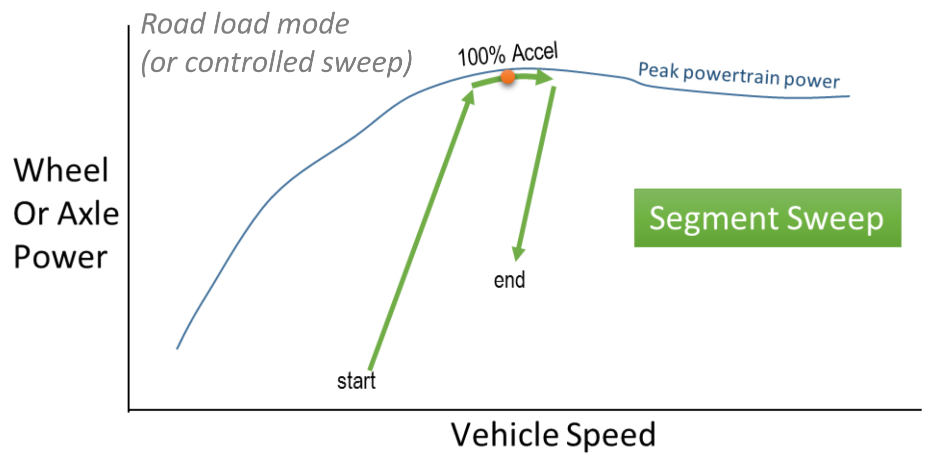
  → *Prep procedures must simultaneously satisfy both*
- Procedures for Warmup / SOC%

  All xEVS, start will full charge
  - HEVs:
    - Engine on/off changes SOC considerably in steady-state.
    - Instead of steady-state, alternative to **prep by running at least 2xHWY cycles**
    - Target SOC: “normal SOC”
  - PHEVs in CD:
    - Warmup: invoke engine start, if it starts
    - Drive 100 km/h for 10 minutes
    - If discharges too much (less than 33% usable SOC in CD mode) limit driving to stay above 33% of usable SOC)
  - BEVs (or EREV in CD):
    - Warmup: Cant be both <u>warm</u> and <u>fully charged</u>, must run some warmup
    - Drive 100 km/h for 10 minutes
  - FCV
    - Not specified: still need guidance from SAE FC standards team for prep

Varied Test Approaches

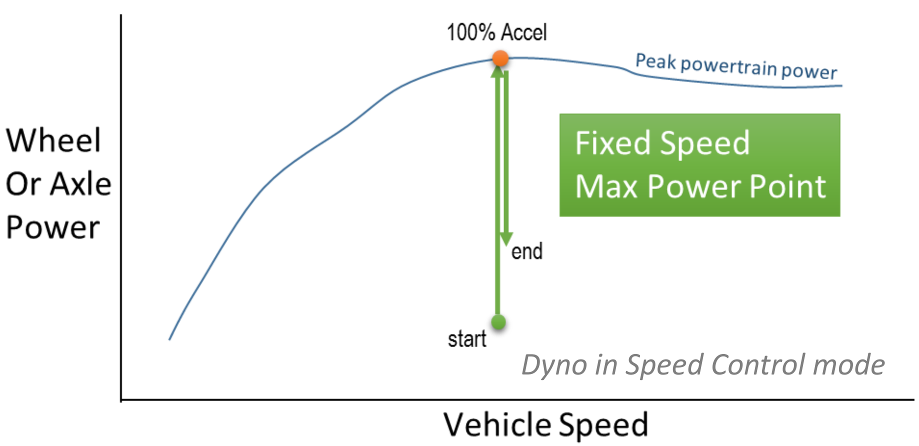
First use "speed" sweep to find Pmax vehicle speed, and then use "fixed speed" to provide Pmax.

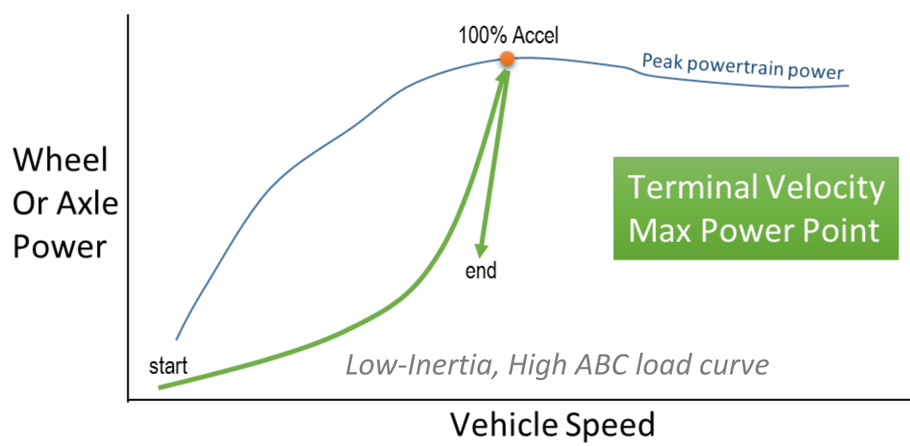




Some power lost to inertia

"Speed Sweep"





More test time, many speeds to test

"Fixed Speed"

J2908-2017 addressed comparisons to engine power as a *future* feature in **Appendix B**

Appendix B: Comparing J2908 Power to "Engine Power" (J1349 or UN R85)

Whereas this document prescribes a test method for measuring vehicle powertrain power at the wheel, the question remains how these results might be compared to existing vehicle power ratings such as SAE J1349 and UN ECE R85. The general public is most accustomed to "engine power" as the rating comparison metric for vehicles. Wheel power will always be a lower power result due to losses in the powertrain that take power away from the power-producing components as it flows to the wheel.

One strategy to compare advanced new powertrains to conventional ICE vehicles is to apply knowledge of the powertrain efficiencies and calculate an effective "engine" power. But the variation in efficiency of new powertrains would provide unfair comparisons. Given that wheel power is the true metric that provides the "feel" of powertrain power, the way to compare wheel power results to "engine power" results is to apply expected conventional ICE vehicle engine-to-wheel efficiencies for all vehicles. Use Figure B1 below as a guide to make these comparisons.

η = standard engine-to-wheel efficiency

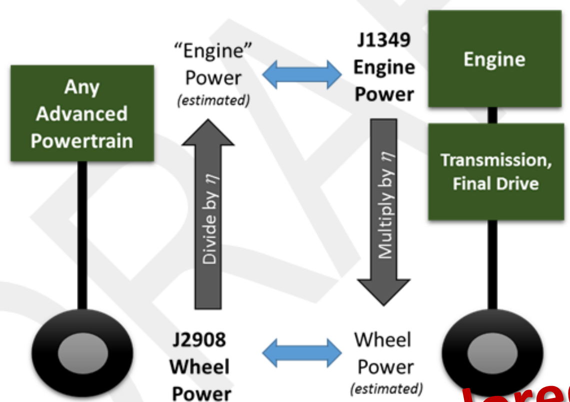


Figure B1: Applying a Standard Engine-to-Wheel Efficiency

The standard efficiency values depend upon the vehicle layouts being compared. For example, all other things equal and ignoring wheel traction limitations, one would expect a rear drive vehicle to put slightly less power to the ground compared to a front drive vehicle due to difference in expected losses from the engine to the wheel. In lieu of better data at publication, the following standard efficiency values are provided.

Generic efficiency values explored → values were removed in final J2908-2017 draft

From small European study comparing measured wheel hub power to published engine power rating

engine-to-hub efficinecy						
*note: hub power / **rated** engine power*						
05 Boxster S 3.2	0.91	man	rear			
03 Fusion 1.6	0.91	man				
02 Focus ST	0.85	man				
05 Focus 1.8	0.85	man				
06 Civic 1.8	0.9	man				
06 Kia Cee'd 1.6	0.92	man				
03 Toyota Avensis 2.0	0.88	man				
04 Corolloa Verso 1.8	0.91	man				
07 Golf 1.6	0.91	man				
Audi TT 2.0 FSI	0.99	man	turbo	(overboost?)		
10 GTI	1.02	man	turbo	(overboost?)		
Saab 9-3 Aero	0.89	auto				
06 Peugeot 407	0.85	auto				
04 Opel 3.2	0.91	auto				
08 Dodge Journey 2.0	0.87	auto				
Fiat Croma 1.9	0.92	auto				
Citroen C5 2.0 Hdi	0.9	auto				
Citroen C1 1.0	0.9	auto				
96 Galaxy 2.8	0.85	auto				
99 Sonata 2.4	0.82	auto			**Averages:**	
02 Lexus RX300	0.79	auto AWD			**0.891**	**Manual FD**
Audi S6 5.2	0.81	auto AWD			**0.865**	**Auto FD**
06 Subaru B9 Tribeca 3.0	0.81	man AWD			**0.847**	**Auto Rear**
					0.800	**Auto AWD**
07 MPS 2.2	0.95	man				
MB C320 3.2	0.84	auto	rear			
MB E320 3.2	0.83	auto	rear			
02 MB CLK 3.2	0.87	auto	rear			
Nissan Primera 2.0	**0.77**	**CVT**				

Average values

Standard Engine-to-Wheel Efficiency	Type of Vehicle Layout
0.865	Front drive, automatic transmission
0.847	Rear drive, automatic transmission
0.800	All-wheel drive, automatic transmission

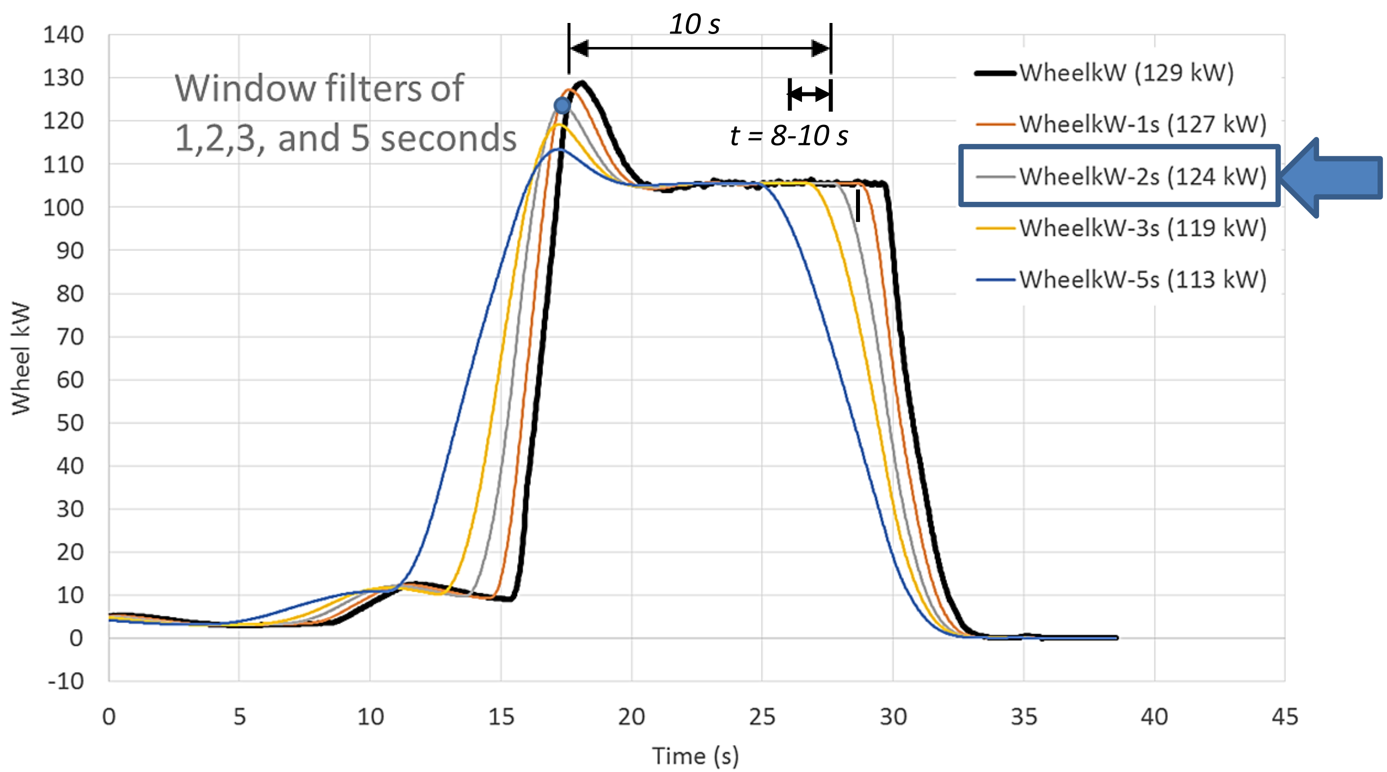
We were looking for an industry-wide consensus on numbers to fill out this table?

In application, if J2908 were used to measure wheel power for a complex HEV powertrain with a front wheel drive layout and an automatic transmission, the result can be divided by 0.865 (increasing the value) and the resulting value can be expressed as "compare to a ___ kW engine rating."

J2908 harmonized with ISO and EVE

Impulse: 1) Peak of 2s Window Moving Average

Sustained: 2) Last 2 Seconds of 10 s Window

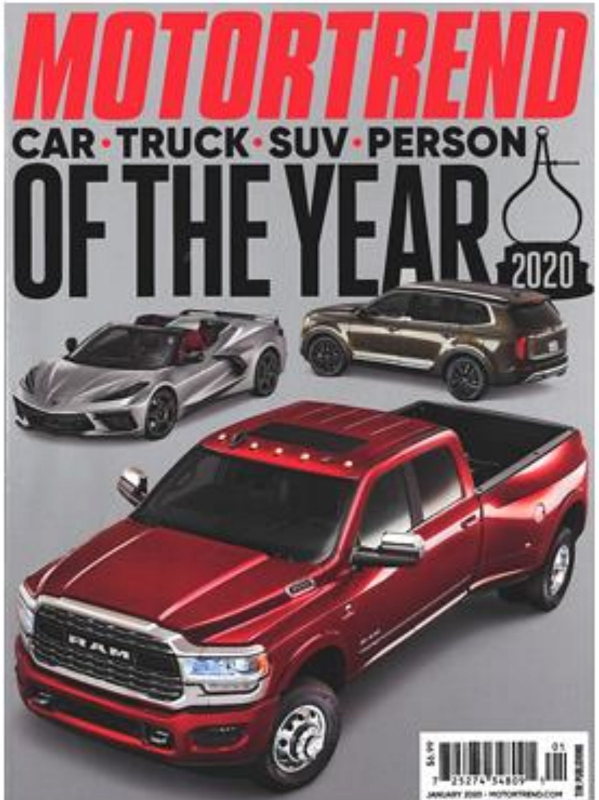


Other tests in J2908:

Have yet to find interested users

- **Electric Assist** Power Rating (*essentially battery power*)
  - 2s moving average
- Electric **Regenerative Braking** Power Rating
  - 2-sec moving window
  - Requires long, high-speed regen in order to maintain peak long enough
- PHEV **Electric-only power** – 0.3 to 0.5 sec moving average
  - Procedure ramps power until engine start, 2s window not applicable as power is always increasing (not stable)

Reopening J2908 in 2020



SPECS	2020 Lincoln Aviator AWD	2020 Lincoln Aviator AWD (Grand Touring PHEV)
Base Price/As Tested	$54,695/$74,920	$71,575/$90,645
Power (SAE net)	400 hp @ 5,500 rpm	400 hp @ 5,500 rpm (gas) + 100 hp @ 2,500 rpm (elec); 494 hp @ 5,500 rpm comb
Torque (SAE net)	415 lb-ft @ 3,000 rpm	415 lb-ft @ 3,000 rpm (gas) + 221 lb-ft @ 1,500 rpm (elec); 630 lb-ft @ 2,250 rpm comb
Accel, 0-60 mph	5.4 sec	5.4 sec
Quarter Mile	14.1 sec @ 97.7 mph	13.8 sec @ 102.3 mph
Braking, 60-0 mph	124 ft	119 ft
Lateral Acceleration	0.80 g (avg)	0.83 g (avg)
MT Figure Eight	27.1 sec @ 0.69 g (avg)	26.5 sec @ 0.72 g (avg)
EPA City/Hwy/Comb	17/24/20 mpg	Target: 18 mi EV; 23 mpg (comb)

SPECS	2019 Porsche Cayenne E-Hybrid (PHEV)
Base Price/As Tested	$80,950/$96,790
Power (SAE net)	335 hp @ 5,300 rpm + 134 hp @ 2,800 rpm (elec); 455 hp comb
Torque (SAE net)	332 lb-ft @ 1,340 rpm + 295 lb-ft @ 100 rpm (elec); 516 lb-ft comb
Accel, 0-60 mph	4.2 sec
Quarter Mile	12.7 sec @ 110.2 mph
Braking, 60-0 mph	113 ft
Lateral Acceleration	0.87 g (avg)
MT Figure Eight	25.4 sec @ 0.78 g (avg)
EPA City/Hwy/Comb	13 mi EV, 22 mpg (gas)/46 mpg-e (comb)

SPECS	2020 Mercedes-Benz GLS 450 4Matic	2020 Mercedes-Benz GLS 580 4Matic
Base Price/As tested	$76,195/$98,420	$98,795/$124,255
Power (SAE net)	362 hp @ 5,500 rpm + 21 hp (elec); 362 hp comb	483 hp @ 5,500 rpm + 21 hp (elec); 483 hp comb
Torque (SAE net)	369 lb-ft @ 1,600 rpm + 184 lb-ft (elec); 369 lb-ft comb	516 lb-ft @ 1,600 rpm + 184 lb-ft (elec); 516 lb-ft comb
Accel, 0-60 mph	5.8 sec	5.4 sec
Quarter-mile	14.3 sec @ 97.0 mph	14.0 sec @ 101.7 mph
Braking, 60-0 mph	113 ft	122 ft
Lateral Acceleration	0.87 g (avg)	0.83 g (avg)
MT Figure Eight	26.4 sec @ 0.70 g (avg)	26.8 sec @ 0.70 g (avg)
EPA City/Hwy/Comb	19/23/21 mpg	Not yet rated

- Media confusion about "SAE power" for hybrid pickup trucks?
- Request was for J2908 to be **comparable to engine power**

UN EVE Group (ECE)

United Nations ECE/TRANS/WP.29/GRPE/2020/12

Economic and Social Council

Distr.: General
24 March 2020

Original: English

Economic Commission for Europe

Inland Transport Committee

World Forum for Harmonization of Vehicle Regulations

Working Party on Pollution and Energy

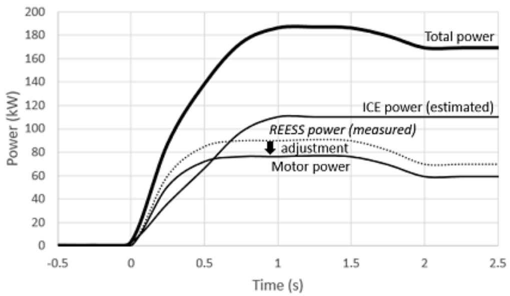
Eighty-first session
Geneva, 9-12 June 2020
Item 9(a) of the provisional agenda
Electric Vehicles and the Environment (EVE):
UN GTR on the Determination of Electrified Vehicle Power (DEVP)

Proposal for a new UN GTR on the determination of system power of hybrid electric vehicles and of pure electric vehicles having more than one electric machine for propulsion - Determination of Electrified Vehicle Power (DEVP)

Submitted by the Informal Working Group on Electric Vehicles and the Environment (EVE)*

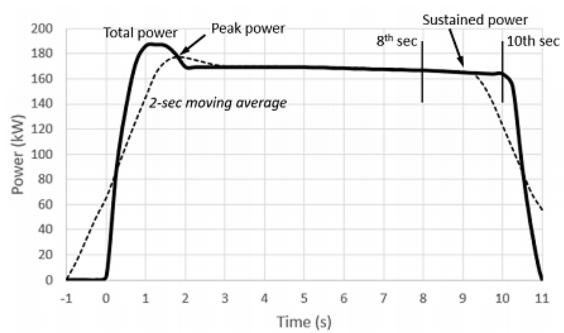
The text reproduced below was prepared by the Informal Working Group (IWG) on Electric Vehicles and the Environment (EVE) following the authorization given by WP.29/AC.3 to develop this UN GTR (ECE/TRANS/WP.29/AC.3/53/Rev.1). A first draft of this proposal was made available as an informal document (EVE-33-05e) by the EVE IWG at the 80th session of GRPE (see informal document GRPE-80-36).

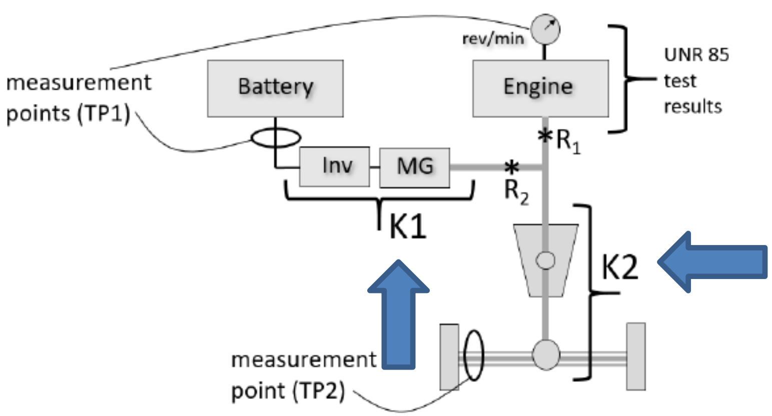
Figure 4
TP1 as sum of estimated engine power and estimated motor power



47. TP2 is similar to SAE Method 3. Total power is the power measured at the wheels or axle shafts, adjusted by a factor (known as η_{gb}) that represents losses in the gearbox. Default values for η_{gb} are provided for a number of hybrid drivetrains. Figure 5 illustrates how total power is modeled under TP2.

Figure 7
Definition of peak and sustained power





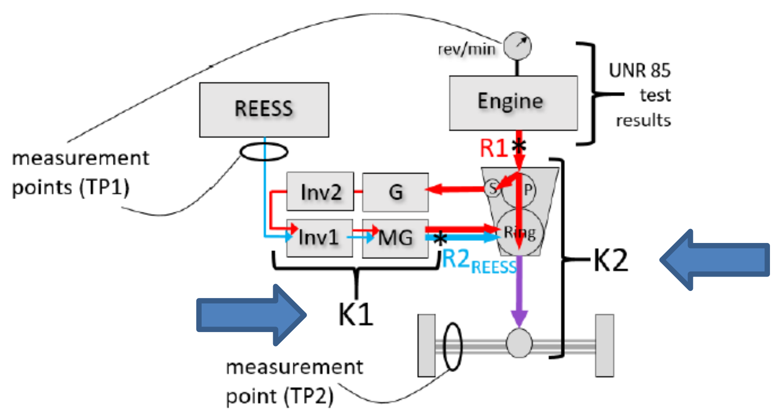
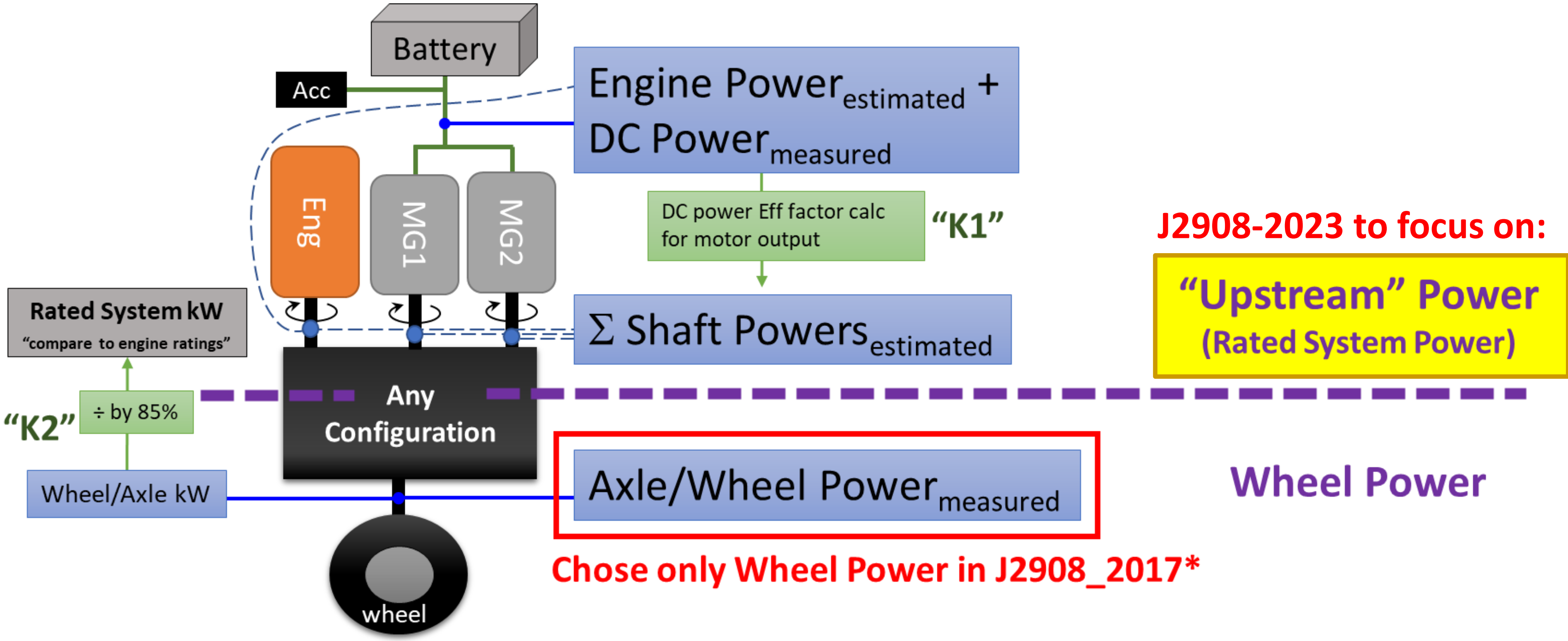


Figure 9. Power split hybrid, ambiguous under TP2
P = planet carrier and gears; S = sun gear; Ring = ring gear

Defining “k-factors” for J2908?



Tried to find suitable "k" values from testing

→ use "standard k-factors"? → what to do when 2 methods give different answers?

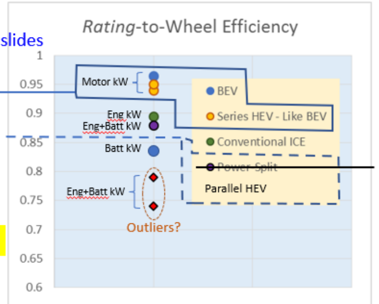
True Power is at the Wheel, Similarities in Efficiency Indicate **Comparability**

Proposed Kf's(K2s): Refer to prior sent slides for detail on how they were derived.

0.94 FWD , AWD

0.86 FWD, e-motor assist
0.86 RWD, e-motor assist
0.84 AWD, e-motor assist
0.86 FWD, e-RWD assist

Any concerns, issues with the above?



Power split HEV (with eCVT) would use different value – WIP leaning toward 0.87 with higher trans efficiency

- ***Motor**-to-wheel* efficiencies for the series HEVs are similar to BEVs
- ***Eng+Batt**-to-wheel* efficiencies for the series HEVs using are outliers (very low)
- Low efficiency means an inflated power rating, OEMs will choose the highest power rating available.
- Given the data above, series HEVs would be better treated like BEVs, if there is concern about fairness then all BEVs are treated unfairly because of their high efficiency.

3

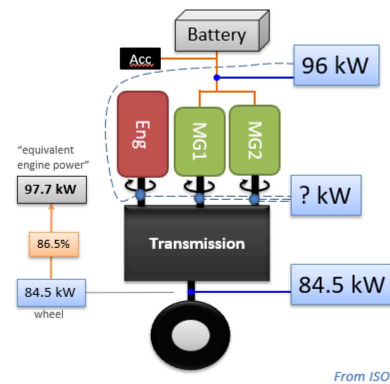
Power-Split HEV

Comment: All methods agree well. K2 from Toyota may work because it was estimated from TP1

From ISO Doc: SC37 N0099 ISO/CD 20762 20170309

K: conversion factor from electrical power to mechanical power (0,85 or measured value). Conversion factor is defined as output power of motor divided by input power of inverter. 0,85 is applicable to PMS motor. In case of other types of motor, the K of the system at the max power shall be provided. US will provide K factor for induction motors.

0.92 mot * 0.93 inv = **0.85 K1**



TP1
75 eng +
21 batt * 0.85
= 75 + 16 = **91 kW**

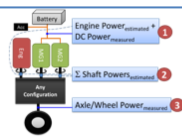
50/50 approach (ave of TP1 and TP2 with no K factors)
(96 + 84.5) / 2 = **90.2 kW**

TP2
84.5 axle / 0.93 = **90.8 kW**

From ISO Doc: SC37 N0099 ISO/CD 20762 20170309

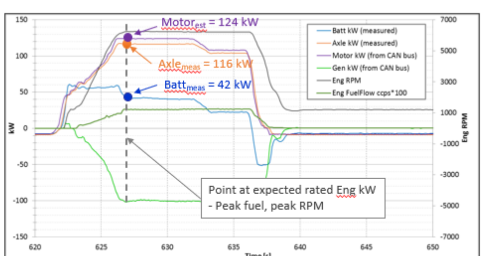
ηGearbox (Power split HEV, planetary gear transmission system) =0,93

Application of Methods on Series HEV



- Engine appears to be at rated power (from data)
- **Method 2:** Total power = Motor Power (CAN bus RPM and torque)
- **Method 1** and **Method 2** are 23 kW different
- **Method 2** and **Method 3** are different by only 8 kW

Engine >> Motor-Generator1/Inverter =
105 *0.98 *0.85 = 87.5 kW
+
Battery output >>Inverter>> Motor-Gen2 =
42 *0.98 0.85 = 35.0 kW
122.5 kW total motor (very close to 124 kW)



Current OEM Catalog Ratings
Engine: 105.1 kW
Motor: 123.8 kW
Total: **123.8 kW**

Method (1)
105.1 + 42 = **147.1 kW**
(rated engine kW + measured battery kW)

Method (2)
Series HEV output = only Motor kW
Motor output: **124 kW**
(from CAN bus)

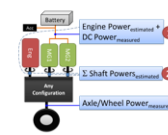
Method (3)
Total: **116 kW**
(measured axle power)

Kf = 116/122.5 = 0.95, very close to coarse model 0.94 Kf

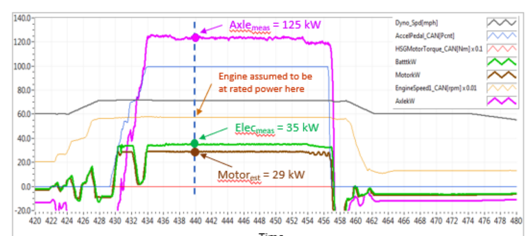
Using Kf of 0.94 from coarse model would have yielded 116/0.94 = 123.4 kW, very close

9

Application of Methods on Parallel HEV



- Engine appears to be at rated power (from data)
- Method 1 and Method 2 are similar in value (small battery assist)
- As expected, Method 3 provides much a lower power rating than the other two.



Current OEM Catalog Ratings
Engine: 123.7 kW
Motor: 30 kW *(mechanical)*
Total: **153.7 kW**

Method (1)
123.7 + 35 = **158.7 kW**
(engine rating + measured battery power)

"Method (2)
123.7 + 29 = **152.7 kW**
(engine rating + reported motor power)

Method (3)
Total: **125 kW**
(measured axle kW)

Implied combined inverter and motor efficiency = 29 / 35 = 0.83 or 83%.
Coarse model uses 0.98 * 0. 85 = 0.83 or 83%.
Not bad!

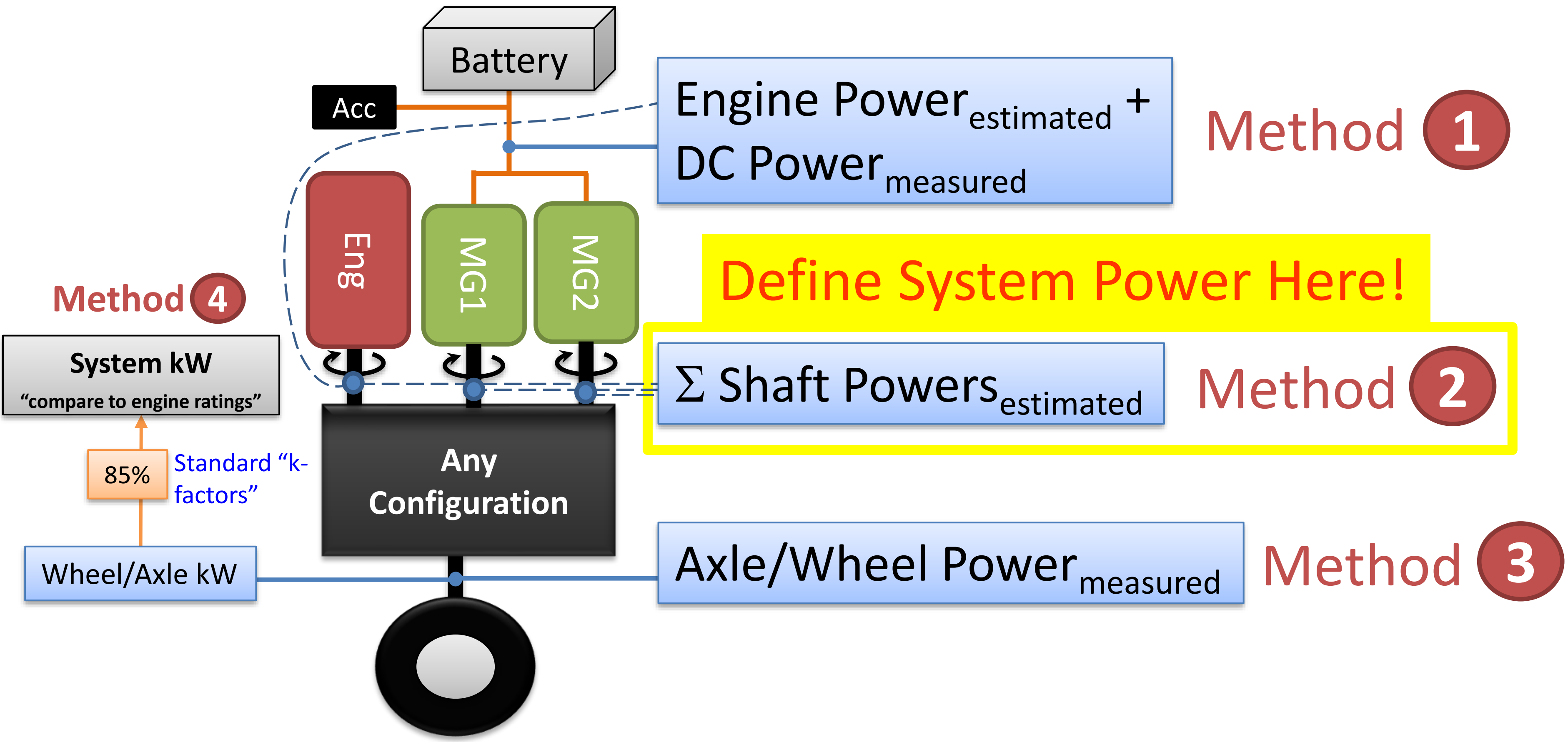
Kf = 125/152.7 = 0.82

e presenter's mark-ups on slide

Using Kf = 0.86 from coarse model would make Method 2 total = 125/0.86 = 145.3 kW,
% diff = (152.7-145.3/152.7) * 100 = 4.8%.
Both 0.82 and 0.86 are within the 95% scatter bandwidth of the Monte Carlo simulation.

5

Unify approaches with a single definition of "System Power" for all types of xEVs?

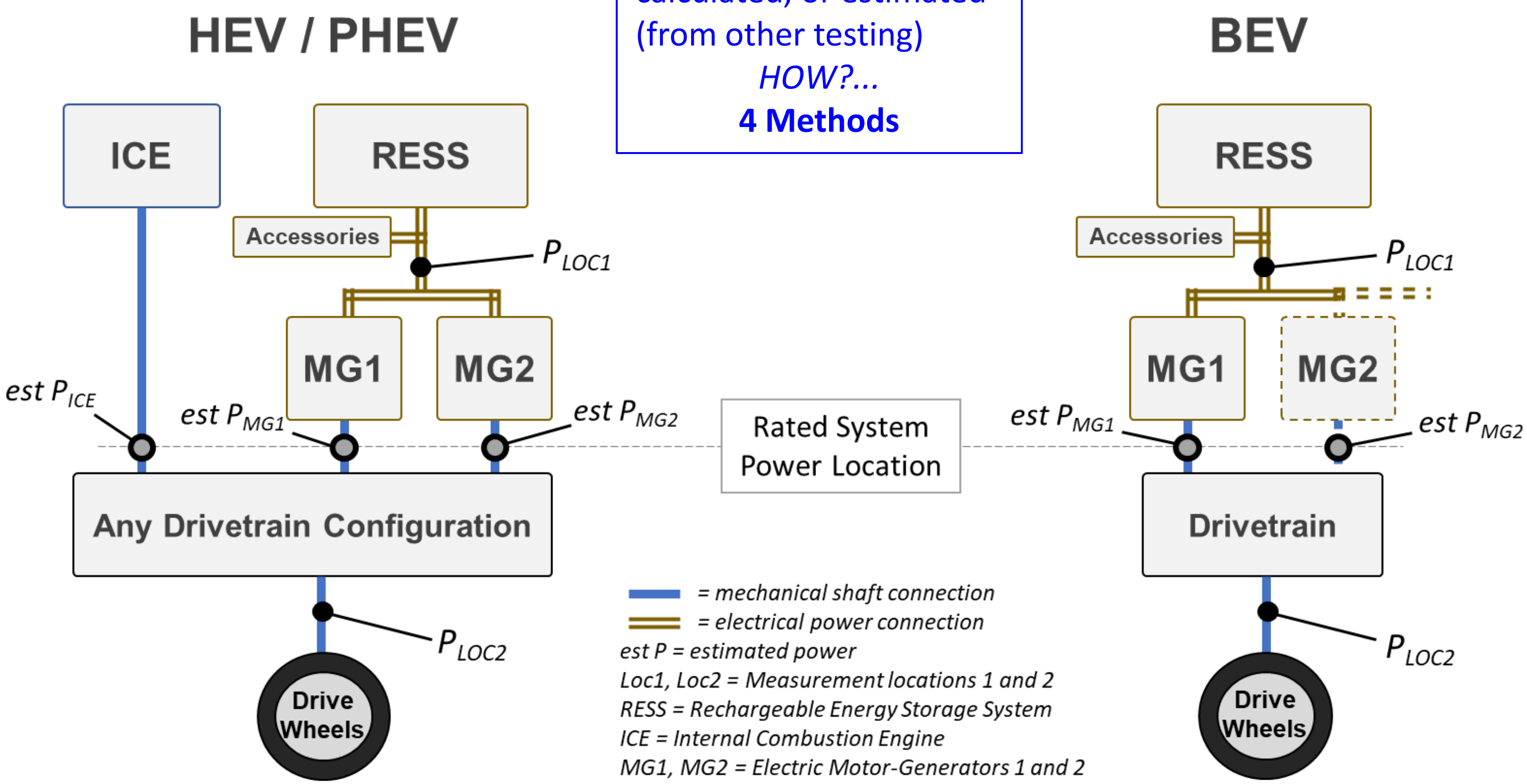


No mattery HOW result is derived, uniform definition allows reproducibility (if result is accurate)

Test information is either measured, inferred, calculated, or estimated (from other testing)

HOW?...

4 Methods



System Power Rating = $est\ P_{ICE} + est\ P_{MG1} + est\ P_{MG2}$

$P_{LOC1} * K1 = est\ P_{MG1} + est\ P_{MG2}$

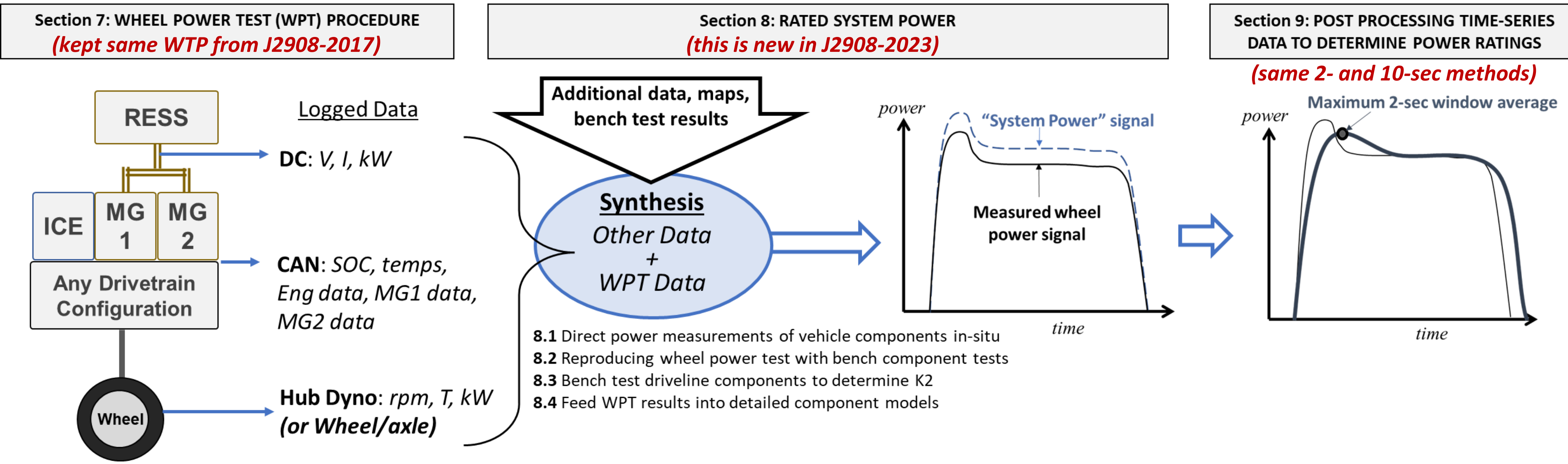
$P_{LOC2} / K2 = est\ P_{ICE} + est\ P_{MG1} + est\ P_{MG2}$

System Power Rating = $est\ P_{MG1} + est\ P_{MG2} + ...$

$P_{LOC1} * K1 = est\ P_{MG1} + est\ P_{MG2} + ...$

$P_{LOC2} / K2 = est\ P_{MG1} + est\ P_{MG2} + ...$

J2908-2023 Process: 4 Methods



#1 Direct Power Measurements of Individual Components In-Situ
Power from each mechanical component contributing to the propulsion of the vehicle be instrumented to directly measure shaft output power in the vehicle during the WPT.

#2 Reproduce WPT with Bench Component Tests
First run WPT and collect comprehensive dataset from all propulsion components. Subsequently, either the propulsion components are removed, or identical components are acquired for additional testing. The components are individually "bench tested" by accurately "replaying" WPT. Like #1 all individual component powers are directly measured and summed to determine rated system power.

#3 Bench Testing Drivetrain Components to Determine Efficiency Factor K2
Drivetrain efficiency measured directly from test. (Drivetrain = the series of rotating components and gears between the power-producing components and the wheels). Then use the "factor K2" method. Most appropriate where transmission power losses are easier to measure than propulsion components.

#4 A Priori Component Data, Models, or Real-Time CAN Data
This method uses pre-existing component performance data in the form of maps, models, and/or efficiency factors presumably from bench tests. The component data or models are applied to the signals, parameters, and states collected from the WPT. The component models or data maps are applied to the WPT results in post-processing, or in real-time (CAN data).