The Column with Sven Andersson .se

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# The Game of Deception
# Horse power [Hp] or Donkey power [Dp] that's the question!

*Sven Andersson is a sports car enthusiast and writes in the RRI Column on an irregular basis on controversial subjects relating to cars in general and car performance in particular. Andersson has devoted half a life-time in the world of cars and has insights in everything from the car industry to the opinion of the everyday motorist.*

**In this the final of a total of four issues, formed as four different chapters, the RRI Column's Sven Andersson will try to give you answers for most of the common concerns about performance measurements. This particular issue deals with the concept of Donkey power.**

There are a lot of questions and beliefs about engine and powertrain performance at almost any automotive web-site or forum, all over the Internet. The performance issue (speed [rpm], torque [Nm], power [Nm, Bhp] and acceleration rate [rpm/s]) is not easy to explain due to the abstract and complex physics involved.

Please consider that I will only talk about powertrain performance due to the fact that this is the only performance statement that is affordable to verify for most performance customers.

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# The Game of Deception, chapter 1, February 26, 2010

Most important document, the same or falsified specification, misleading with performance measurements and a method of performance deception.

**Q0: What is the most important document for demanding performance customers?**

**A0:** The Powertrain Performance Graph(s), PPG, supplied by professionals. The PPG document is an essential for all new or used cars, standard or modified, performance or racing cars. Without a Powertrain Performance Graph from the actual car, performance customers are vulnerable to inaccurate information.

**Q1: Do all engines with the same specification perform at the same level?**

**A1:** **NO!** Engine performance and the causes to variations in performance. Production tolerances are something all manufacturers struggle with. Some have too wide tolerances or defects in production for mechanical parts, (cylinder heads, pistons, cylinders, camshafts) sensors, fuel injectors etc. All components are slightly different (even within specification) and this will have an effect on the total performance. The goal for the manufacturer is to have a robust design that is not sensitive to tolerances. However, the difficulty and expense increases with performance and the complexity of the design. One way to reduce the effect of tolerances is to use engine adaptation, which will to some degree compensate for the variations.

Stated maximum torque and power are allowed to vary in the production within ±5% in EC / according to ISO standard. It is then up to the manufacturers to maintain as little variation as possible. Some try to maintain the he average variation as closely as possible, whereas others try to stay within the specific interval, and whilst others struggle to keep it above the lower limit.

It is important to remember that the specifications are certified in an engine dynamometer with more or less unlimited cooling. This also incorporates long stabilization times before the actual performance measurement. This opens possibilities, for instance, to use over-boost functions for shorter periods. Additional power consumers, i.e. air conditioning, servo pumps, cooling fans, etc may reduce the available performance from the engine.

The installation in the vehicle can affect the output. A very cramped engine installation may give local heating problems. Routing of inlet air can easily raise the temperature and reduce performance. There are also installation effects (defects) from exhaust systems- and engine cooling capacity problems, too high exhaust back pressure and too high water cooling temperature due to high demands for head wind cooling. The engine cooling system (radiator) may be designed for a maximum "surrounding temperature" of for example +30°C and above that temperature, the engine control system has to reduce the performance output. The engine design may be sensitive to fuel quality and even to test conditions. An engine running close to the border of knocking *may reach the knocking limit* if the atmospheric pressure is high.

**Q2: Is it possible that the stated engine power of my new and/or used car has been falsified?**

**A2:** **YES!** To prove that a manufacturer is misleading is very difficult and that is because of the official test itself. It has to be made on an engine dyno and to remove the engine from a modern vehicle to get it running on the engine dynamometer is practically impossible. The whole car will be needed because the ECU (Engine Control Unit) checks for all the other onboard computers, sensors, etc in the car and if it cannot find them it will not start!

The manufacturer can be close to the lower limit of the allowed tolerance. Whether they choose it deliberately or not makes no difference to the performance customer.

**NOTE!** Automotive customers pay for what is claimed in the engine but they get what is available to the wheel hubs!

Performance may have also been adjusted at normal service work. It is usual that the service station updates the software and in the worst case this may include reductions of performance. The engine performance may be reduced when the engine is used in the car, due to the following; engine over- heating or engine mechanical problems, exhaust emission problems, transmission over load, general reliability problems, all resulting in high warranty costs.

Some sports car / race engines may be specified at a low inlet temperature of +15°C instead of the common +25°C. This will boost the specification of maximum power with approx. 2% only based on the temperature, added to that you may have knocking problems at a higher inlet temperature.

Official tests are done Steady State, but in reality the performance at full throttle (WOT) accelerations are of greater interest. The only Steady State in real life will be at the top speed.

**NOTE!** Performance during accelerations may differ significantly from the Steady State results. Maximum stated power and torque may be outside the usable areas, i.e. automatic gearboxes may shift before maximum power is reached and maximum torque may be specified below the stall speed of the transmission converter.

Maximum power and torque only specifies two points. It might be two narrow peaks and not a good description of the engine performance as a whole. Always demand a Powertrain Performance Graph, PPG over the whole "engine" working area (idle to maximum engine speed).

The market situation may from time to time force some automotive manufacturers to state the "same" performance numbers as tough competitors. In the best case this will be reached during ideal conditions with unlimited cooling.

**Q3: Is it possible to mislead when dealing with performance measurements?**

**A3:** **YES!** Inaccurate measurement systems are common and this is the main reason for the spreading the Donkey power [Dp] statements (please see **A16**) instead of accurate measured [Bhp] or [kW] according to Best Known Practice, BKP.

Some of the dyno concepts, such as the rolling road, are simply not suitable for quality and scientific measurements and they clearly shows that there is a lack of underlying physical understanding and sense of professionalism.

A well-informed performance consumer could easily distinguish this type of garage grade dynos from a true measurement system tool and should always demand true powertrain performance according to Best Known Practice, BKP.

# The Game of Deception, chapter 2, March 5, 2010

Calibration a critical quality issue, measurements during changing acceleration rates good enough, worst case dyno concept.

**Q4: Is use of inaccurate measurement tools a method of performance deception?**

**A4: YES!** A dynamometer has to be a professional measurement device not only named as such. For example the ROTOTEST VPA-RX chassis dynamometers are designed to meet industrial demands on measurement accuracy, according to Best Known Practice, BKP. A performance customer has always the right to demand high quality and safety for both the car and tyres when purchasing performance measurements.

**WARNING!** Most chassis dynamometers (garage grade rolling roads and/or garage grade hub dynos) have as a best practice a total measurement tolerance of ±7% on the absolute measured value (for the most uncomplicated method, the Steady State measurement). This means 93 to 107 hp for a 100 hp engine, or 279 to 321 hp for a 300 hp engine. In most cases this implies less than accurate measurements. For a race car Powertrain Performance measurements with such low level of accuracy chances are small to perform a winning engine calibration and it is not possible to carry out a professional investigation on why the car is not fast enough.

Another method used to claim false measurement accuracy is to show relative measurements during a short period. Often is a test car used as an example, head lights on and off for example. This type of demonstrations only shows that the test equipment has a good sensitivity for small power outputs. It tells nothing about calibrated absolute measurement accuracy. For calibration please see **Q5** below.

**NOTE!** A clock that stand still, show you the absolute right time twice, every 24 hours!

**Q5: Is dynamometer calibration a critical quality issue?**

**A5: YES!** Always ask for the calibration procedure for the used dynamometer and with what accuracy the total measurement change is performed. Any calibration of only the torque- or "pressure" sensor will not tell the whole story, *it must be a calibration of the total measurement chain*, with tyres and parasitic losses (rolling roads). Second hand measurements (hydraulic pressure instead of torque measurements for hydraulic garage grade

dynamometers) are not good enough for professional usage. If your questions are not answered properly, do not waste your money, use another test supplier.

**Q6: Is use of inertia engine and inertia chassis dynos with measurements during changing acceleration rates good enough?**

**A6: NO!** Uncontrolled acceleration engine or/and chassis dynos will always give measurement that are not possible to compare - so called Donkey power [Dp] (see **A16**) due to non-constant acceleration rates [rpm/sec]. Measurement results will change with the acceleration rate, when using a known inertia [$kgm^2$] (a drum, flywheel etc.) as a braking device. The acceleration rate will change with the engine power output:
**More power = more braking, less power = less braking!?**

**The inertia influences:** The larger inertia (flywheel), the larger "mechanical filtration" of the test results (The power variations will be hidden due to the physics of a flywheel).

**NOTE!** Flywheels are used in combustion engines to smooth out torque variations.

**WARNING!** *Inertia engine and chassis dynamometers are a low cost unprofessional dynamometer solution!*
Performance graphs from these types of garage grade dynos do not in any way give correct test result for comparing of performance.

**NOTE!** Test results are not comparable in any way (due to acceleration rate fluctuations), even between test runs at the same "acceleration garage grade dyno".

**Q7: What is the worst case dyno concept?**

**A7:** The "Road Dyno" is a computer box, measuring the engine speed. This concept uses the same physical background as the inertia rolling roads or engine dynos. The base concept is useless due to performance measurements during non constant acceleration rates [rpm/sec]. A "Road Dyno" has all of the worst drawbacks of the rolling road. Non constant acceleration rates instead of Steady Rate™ [rpm/sec], its dependence on powertrain inertia, the tyre - road traction, used gear, plus a couple of other variation factors as wind speed, road slope angle, weight of the vehicle, aero dynamics of the vehicle and dragging brakes.

The many uncertainties with this type of attempt to measure performance are why racing engineers (with

advanced data acquisition systems) cannot claim missing engine performance, despite well grounded suspicions.

**NOTE!** "Road Dynos" could be used as a toy, just for fun, but absolutely not in professional performance measurements.

# The Game of Deception, chapter 3, March 12, 2010

Second worst case dyno concept, inadequate measurements, fantasy estimations of transmission losses, quality factors for rolling roads and importance of inlet temperature measurement.

**Q8: What is the second worst case dyno concept?**

**A8:** The inertia, uncontrolled acceleration concept combined with a tyre grip dependable rolling road is frighteningly common and is also a real assault at true measurements of Powertrain Performance.

**Q9: How does the use of inadequate measurement equipment influence the claims for Powertrain Performance™ in general?**

**A9:** Measurement equipment with large result tolerances, such as tyre grip dependable rolling roads, or garage grade hub dynos without adequate measurement devices for torque and speed are useful tools for performance deception in the following ways:

**1)** Several tests are performed and since all of them give different results, the "good results" can be sorted out. The selected "good results" are then used as evidence for performance improvements.

**2)** Chassis dyno manufacturers who claim measurement of engine power. These false claims are based on lack of physical and powertrain knowledge. For more information please see The RRI white paper *"Why powertrain performance measurements?"*. These false claims are also used for attempts to compare auto manufacturer's statements for engine power at a steady state (please read more about steady state and steady rate measurements below).

**NOTE!** With a chassis dynamometer it is only possible to measure Powertrain Performance.

**Q10: Are there fantasy estimations of transmission losses?**

**A10: YES!** Another way to deceive is to use a garage grade dyno with built in systems for adding transmission loss factors to the Powertrain Performance measurements for "engine power" statements. In a few cases the transmission factors claim to originate from some of the auto manufacturers!?

**NOTE!** Claims for the worst case of transmission losses, for vehicles with automatic transmissions and 4WD over 15%, are almost always untrue.

**WARNING!** Chassis dynamometers, (garage grade rolling roads and hub dynos) with these built-in features they are not capable of issuing truthful Professional Performance Graphs, PPG.

**NOTE!** The transmission losses are not in a fixed proportion to the engine power. The losses change with engine load and speed, used gear etc. and also with the individual tested vehicle. A fixed factor for the transmission losses are always an approximation. The transmission losses have a variation of approximate 2% between different vehicle individuals of the same vehicle specification and even more at different loads and speeds.

**NOTE!** If users of chassis dynamometers make a statement, about the engine performance with a published figure for used transmission losses (5-12%, depending on transmission design), that is satisfactory, as *an approximate statement for engine power*.

**RECOMMENDATIONS!** Use only professional performance suppliers, using test equipment, which produces test results, according to Best Known Practice, BKP, which can be checked by other performance professionals. Powertrain Performance™ measurements on professional test equipment will only produce small variations in test results (within a few %, including both measurement tolerances and other variations).

**WARNING!** A performance statement that cannot be reproduced by others despite cause is a strong warning for potential deceivers and "Donkey power [Dp] (see **A16**) results.

**Q11: Is changing tyres and/or vehicle position between test runs a quality factor for rolling roads?**

**A11: YES!** This is an issue on tyre dependent rolling roads. Different tyres will give different results and these can be used for falsifying performance results. Rolling roads are also sensitive to the position of the tyres on the roller, different positions will give different traction and the

traction will differ with the applied torque. These two circumstances are two of the main obstacles for accurate measurements on a rolling road; the dependence of tyre traction and the dependence on tyre-roller position. These two conditions are both open for misleading performance results.

**Q12: Is the location of engine inlet temperature measurement important?**

**A12: YES!** The engine inlet temperature should be measured in the inlet duct to the engine before the air filter. If the inlet temperature is measured after the air filter or even closer to the engine inlet channels the temperature correction will be to large (more power) due to a higher inlet temperature.

ISO 1585 correction formula:

$$f_c = \left(\frac{990}{p}\right)^{1.2} \cdot \left(\frac{T + 273}{298}\right)^{0.6}$$

where
$f_c$ is the correction factor applied to power and torque
$p$ is the dry absolute atmospheric pressure, expressed in mbar
$T$ is the inlet air temperature, expressed in °C

**NOTE!**
8 mbar higher atmospheric pressure ≈ 1% more power
5°C lower inlet temperature ≈ 1% more power

# The Game of Deception, chapter 4, March 19, 2010

Steady state performance vs measurements during acceleration and what is Donkey power [Dp].

**Q13: Is it common that steady state performance measurements can be confused with measurements during acceleration?**

**A13: YES!** Steady State measurements are generally not comparable with measurements during acceleration conditions! Measurements of Powertrain Performance during acceleration or dynamic conditions will always be affected by the powertrain inertia due to the energy consumed (stored) in the rotational inertia of the powertrain components, such as the engine flywheel.

Performance measurements during acceleration with varying acceleration rates are not comparable in any way, results from road dynos, garage grade rolling roads and hub dynos and engine dynamometers with no accurate speed control for constant acceleration rates. There are also, in many cases, a lack of correction methods for minor fluctuations in the acceleration rate.

**NOTE!** Acceleration speeds less than 100 Engine [rpm/second] (an increase of 1000 to 7000 engine rpm in a minute) are approximately comparable to steady state measurements.

**Q14: What about performance measurements at steady state?**

**A14:** Steady State is the standard test condition used by the automotive manufacturers. The Powertrain Performance™ at Steady State is measured at different constant engine speeds. Unless otherwise stated, all tests are conducted at Steady State, i.e. at a fixed engine speed, and the engine is kept at full load (wide open throttle, WOT) until certain conditions are met when the measurements are taken. The engine speed is then changed to the next engine speed usually about 500 rpm apart and/or closer at the expected peak power and torque. The tests conducted by RRI follow the same principal procedure with one important difference — the test equipment on which the tests are conducted. While the engine manufacturer states peak power and peak torque for the engine (at the flywheel) this requires the engine to be tested separately in an engine dynamometer. RRI uses a chassis dynamometer from Rototest that measures the Powertrain Performance™ produced at the wheel hubs. The Rototest chassis dynamometer is very similar to an engine dynamometer with the only difference that it is meant to

measure Powertrain Performance instead of engine performance.

**NOTE!** Test point times at Steady State less than approx. 3 seconds are not appropriate due to normal engine output variations. A longer test point time gives more information about engine cooling capacity. The measurement points are joined by a line only for display purposes. There is no information about Steady State Powertrain Performance between the measurement points. At Steady State there is no performance influence due to the inertia of the powertrain (e.g. engine flywheel).

**Q15: What about performance measurements at steady rate (constant acceleration)?**

**A15:** Measurement during acceleration will always lose some power due to the acceleration of the powertrain inertia (the engine flywheel, gear wheels etc.). On the other hand, the engine control software is able to give you different engine control parameters during acceleration. In this way some engines are able to produce more power during acceleration in spite of the power losses due to acceleration of the powertrain inertia. A common example is over boost during short times. To be comparable the acceleration rate, Steady Rate must be the same, for example 300, 500, 700, 1000 rpm/s.

**NOTE!** The acceleration rates must be performed within close tolerances. For Best Known Practice, BKP *the acceleration rate must be present at the Certificate of Powertrain Performance, CPP.*

**Q16: What is Donkey power [Dp]?**

**A16:** For Horse power [Hp] and kilo Watt [kW] there are standard definitions. However for Donkey power [Dp] there is no standard (ISO/SAE) definition.

**Donkey power [Dp] is characterized by:**

- Unspecified "Power" (engine power or Powertrain Performance) with no standard support for definition and control and due to that a total lack of scientific value.
- Power result from measurement equipment (dynamometer) with none or a defective calibration procedure.
- Power measured during changing acceleration rates.
- Power measured during constant acceleration without declaration of used acceleration rate [rpm/s].
- Power results fabricated by calculations or "so called measurements" from a non-professional dynamometer.
- Engine power measured by a chassis dynamometer.

• Performance graphs without background information such as: atmospheric pressure [mbar], inlet temperature [°C], acceleration rate [rpm/s], used correction method (standard) and test company information.
• Power claims in general generated from non-professional measurements.

**Warning signs for Donkey power [Dp] claims:**

• Usage of test results that cannot be verified by others.
• Performance graphs without background information.
• The power and torque graphs are not corresponding.
• Attempt to compare power and torque graphs from Steady State with Steady Rate™ measurements or worse, comparing power and torque graphs from measurements during changing acceleration rates (cheap rolling roads, hub dynos and/or so called road dynos).

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