

Standard for Dynamometer Testing of Performance Engines and Vehicles

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[Reviewers of this document please note, while everything is subject to change, those things **marked in yellow** are *really* subject to change due to lack of data, facts, knowledge and/or clues. Also, for this to be useful, many of the terms used need to be defined and discussed. An electronic “web page” format might be used where a user could click on a term, go to the definition/discussion, then click the back button and continue where they left off.]

Who

This standard is to be used by those using dynamometers (engine dynamometers or chassis dynamometers) to test engines and vehicles which have been (or are going to be) modified from their original form. Typically the purpose of the modification is to increase performance. As a result, the typical user of this document will be involved some part of the aftermarket industry and will be mainly interested in increases in speed, torque and horsepower. This includes manufacturers of performance parts, shops that modify engines and vehicles for use on public highways or in racing, and anyone who purchases the services of one of these organizations.

Why

Dynamometer testing is, by its very nature, a complicated job. Many things influence the amount of power an engine produces, and others influence how accurate the measurement of that power really is. Many claims are made about the power increases that result from the use of a particular part or method and these claims are often backed up by the results of dynamometer tests. Unfortunately, the difficulty of making accurate tests on dynamometers makes it hard to know if the claimed increase in horsepower is real. Up to this point there has been no documented standard way for those in the aftermarket industry to determine how “good” a dynamometer test really is. This standard will describe **TBD** levels of equipment and procedures. Each level will correspond to an estimated confidence “bracket”. These accuracy brackets are used to determine how close the actual condition is to the measurement.

For example, a manufacturer produces a widget. An engine is selected and the engine is tested on the company’s dynamometer. Let’s say the engine’s horsepower is measured at 250 HP on a dynamometer with a full scale capability of 1,000 HP. Then the widget is installed and another dynamometer test is done. This time the engine’s horsepower is measured at 290 HP. The claim is made that the widget will result in an increase of 40 HP, and the test results are published

(typically in an advertisement) to back up the claim. Unfortunately, there is no way to determine the quality of the measurement. If we don't know the quality of the measurement, we have no way to know how likely it is to be accurate. The mere recording of a number off of a meter is not enough.

Using the above scenario, lets assume that the widget really has no effect, and that the engine produces 270 HP. It's possible that when the engine was tested prior to the installation of the widget, the dynamometer was reading 2% low. If that were the case, the dynamometer would say that the engine's output was 250 HP ($270 \text{ HP} - (1,000 \text{ HP} * .02)$). When the engine is tested again with the widget installed, the dynamometer could be reading 2% high. In this case, the engine is still producing 270 HP but the dynamometer will read 290 HP ($270 \text{ HP} + (1,000 \text{ HP} * .02)$). It will appear that 40 HP is gained when in fact, no change had occurred. The question is, how does this document improve the situation? Using this document, the manufacturer (or the consumer of the widget) could evaluate the dynamometer and determine that the "bracket" his system falls into is $\pm 2\%$. This means that any reading taken might be correct, it might be 2% (of the dynamometers full scale rating) high, or it might be 2% low. The reading of 250 HP might really be 270 HP, or it might be 230 HP. Likewise, the reading of 290 HP might really be 310 HP, but it might also be 270 HP. This would lead the manufacturer (and the consumer) to the conclusion that a claim of a 40 HP increase cannot be made accurately.

The following section is for use with **Engine Dynamometer**:

1. Level 1 System – Accuracy Bracket: $\pm \text{TBD}\%$ of Full Scale

- 1.1. Clean air is provided to the engine.
 - 1.1.1. No engine exhaust is present in the air.
 - 1.1.2. No fuel vapor is in the air.
 - 1.1.3. The air is dry (no spraying or leaking water nearby).
 - 1.1.4. No significant contaminants are present (paint fumes, dust, etc.).
 - 1.1.5. Comparison tests are done under the same conditions to the extent that the conditions can be controlled.
 - 1.1.6. The same test is performed/
 - 1.1.7. Doors and windows in the room containing the engine are in the same position(s).
 - 1.1.8. Any fans or blowers are in the same state (on or off).
 - 1.1.9. The exact same parts, other than the part(s) in question, are used on the engine. This can include the following:
 - 1.1.9.1. Air filter
 - 1.1.9.2. Exhaust manifold(s), exhaust piping, muffler(s), catalytic converter(s), etc.
 - 1.1.10. Tests are done on the same dynamometer.
- 1.2. Torque and horsepower numbers are corrected for altitude (see Appendix A of this document).
- 1.3. Dynamometer has been calibrated per the following:
 - 1.3.1. Within the last 12 months.
 - 1.3.2. Torque has been calibrated using a two point method traceable to NIST (National Institute of Standards and Technology).
 - 1.3.2.1. The low point of calibration was zero.
 - 1.3.2.2. The high point was within 20% of the reading being reported.

- 1.3.3. Speed has been calibrated using a two point method or per the manufacturers recommendation
 - 1.3.3.1. Modern digital electronics make it possible to measure speed with great accuracy and negligible drift over time. If the system contains this type of circuitry, calibration is often unnecessary.
- 1.3.4. Horsepower has been calibrated using a two point method or per the manufacturers recommendation.
 - 1.3.4.1. If the horsepower is calculated in a microprocessor-based computer the horsepower need not be calibrated.

2. Level 2 System – Accuracy Bracket: \pm TBD% of Full Scale

- 2.1. All conditions for above level 1 are met with the following exceptions and additions.
- 2.2. The dynamometer manufacturer specifies that the dynamometer used will measure speed, torque, and horsepower accurate to within \pm TBD% of full scale.
- 2.3. Dynamometer has been calibrated per the above except within the last 6 months.
- 2.4. Engine torque and/or power are corrected for temperature, humidity, and barometric pressure via manual entry of the parameters at the beginning of the test (altitude correction is not needed as it is accounted for when measuring barometric pressure).
- 2.5. Correction factors are calculated per SAE J1341.
- 2.6. Instruments used to measure temperature, humidity and barometric pressure are to be laboratory grade devices with accuracy (specified by the manufacturer) of at least \pm 5%.
- 2.7. Instruments used to measure temperature, humidity and barometric pressure are to be calibrated within the last 12 months.
- 2.8. Temperature, humidity and barometric pressure are to be recorded before and after the test and the before and after numbers are recorded along with any torque or power data.

3. Level 3 System – Accuracy Bracket: \pm TBD% of Full Scale

- 3.1. All conditions for above level 1 and 2 are met with the following exceptions and additions.
- 3.2. The dynamometer manufacturer specifies that the dynamometer used will measure speed, torque, and horsepower accurate to within \pm TBD% of full scale.
- 3.3. Engine torque and/or power are corrected for temperature, humidity, and barometric pressure continuously during the test.
- 3.4. Instruments used to measure temperature, humidity and barometric pressure are to be laboratory grade devices with accuracy (specified by the manufacturer) of at least \pm 1%.
- 3.5. Instruments used to measure temperature, humidity and barometric pressure are to be calibrated within the last 12 months or per manufacturer's recommendation, whichever is shortest.
- 3.6. Temperature, humidity and barometric pressure are to be recorded before and after the test and the before and after numbers are reported along with any torque or power data.
- 3.7. The test is performed by a computer automated system which will assure that the test is performed in the same way each time. This is necessary to remove variances in test execution.

4. Level 4 System – Accuracy Bracket: \pm TBD% of Full Scale

- 4.1. All conditions for above level 1, 2 and 3 are met with the following exceptions and additions.
- 4.2. The dynamometer manufacturer specifies that the dynamometer used will measure speed, torque, and horsepower accurate to within \pm TBD% of full scale.
- 4.3. Dynamometer has been calibrated per the above except within the last 24 hours.
- 4.4. Instruments used to measure temperature, humidity and barometric pressure are to be calibrated within the last 6 months or per manufacturer's recommendation, whichever is shortest.
- 4.5. In comparison tests, fuel used is exactly the same for each test.
 - 4.5.1. This typically requires that the fuel be stored and drawn from in a container large enough so that no additional fuel needs to be added between tests.
- 4.6. Engine operating conditions are to be duplicated within \pm 10%. This often means that these conditions must be controlled by some means. These include the following:
 - 4.6.1. Oil temperature
 - 4.6.2. Fuel temperature
 - 4.6.3. Engine coolant temperature

5. Level 5 System – Accuracy Bracket: \pm TBD% of Full Scale

- 5.1. All conditions for above level 1, 2, 3 and 4 are met with the following exceptions and additions.
- 5.2. The dynamometer manufacturer specifies that the dynamometer used will measure speed, torque, and horsepower accurate to within \pm TBD% of full scale.
- 5.3. Combustion air is to be duplicated within \pm 5%. This often means that combustion air must be controlled by some means.
- 5.4. Dynamometer torque has been calibrated at 10 points and torque data has been linearized via a multi-order polynomial equation.

The following section is for use with a **Chassis Dynamometer**:

[Note to reviewers – The subject of testing computer controlled vehicles with a chassis dynamometer is extremely complex. Following is a list of some of the things, unique to a chassis dynamometer, that can significantly effect the results of the test (thanks to Steve Dinan for a lot of the insight used in this section):

Tire condition, pressure and temperature
Tie down strap force
Differential temperature
Transmission temperature
CV/Universal joint temperature
Wheel bearing temperature
Under-hood temperature
Exhaust manifold temperature
Quantity of cooling air (blower in front of the car)
Position of cooling air blower
Computer adaptation to new parts
How the vehicle was run minutes before the actual test was started

Note that a lot of the above conditions are effected by how the vehicle is run before the test is performed. Quantifying all of the effects of these things is going to be a challenge. I mention it because a lot of input is needed.]

1. Level 1 System – Accuracy Bracket: **±20%** of Full Scale

- 1.1. Clean air is provided to the engine
 - 1.1.1. No engine exhaust is present in the air.
 - 1.1.2. No fuel vapor is in the air.
 - 1.1.3. The air is dry (no spraying or leaking water nearby).
 - 1.1.4. No significant contaminants are present (paint fumes, dust, etc.).
- 1.2. Comparison tests are done under the same conditions to the extent that the conditions can be controlled.
 - 1.2.1. The same test is performed.
 - 1.2.2. Doors and windows in the room containing the vehicle are in the same position(s).
 - 1.2.3. Any fans or blowers are in the same state (on or off).
 - 1.2.4. The exact same parts, other than the part(s) in question, are used on the vehicle.
This can include the following:
 - 1.2.4.1. Air filter
 - 1.2.4.2. Exhaust manifold(s), exhaust piping, muffler(s), catalytic converter(s), etc.
 - 1.2.4.3. Tires (and tire pressure)
 - 1.2.4.4. Tie down straps
 - 1.2.4.4.1. If straps are used, the tension is the same.
 - 1.2.4.5. Transmission (same oil/fluid)
 - 1.2.5. Vehicle is warmed up in the same way.
 - 1.2.6. Tests are done on the same dynamometer.

- 1.3. If the engine is electronically controlled, the engine has been run long enough with the new parts that the computer has adjusted for the changes.
- 1.4. Torque and horsepower numbers are corrected for altitude (see Appendix A of this document).
- 1.5. Dynamometer has been calibrated per the following:
 - 1.5.1. Within the last 12 months.
 - 1.5.2. Torque has been calibrated using a two point method traceable to NIST (National Institute of Standards and Technology).
 - 1.5.2.1. The low point of calibration was zero.
 - 1.5.2.2. The high point was within 20% of the reading being reported.
 - 1.5.3. Speed has been calibrated using a two point method or per the manufacturers recommendation.
 - 1.5.3.1. Modern digital electronics make it possible to measure speed with great accuracy and negligible drift over time. If the system contains this type of circuitry, calibration is often unnecessary.
 - 1.5.4. Horsepower has been calibrated using a two point method or per the manufacturers recommendation.
 - 1.5.4.1. If the horsepower is calculated in a microprocessor-based computer the horsepower need not be calibrated.

2. Level 2 System – Accuracy Bracket: $\pm 15\%$ of Full Scale

- 2.1. All conditions for above level 1 are met with the following exceptions and additions.
- 2.2. Tie down straps are used.
- 2.3. The dynamometer manufacturer specifies that the dynamometer used will measure speed, torque, and horsepower accurate to within $\pm \text{TBD}\%$ of full scale.
- 2.4. Dynamometer has been calibrated per the above except within the last 6 months.
- 2.5. Vehicle torque and/or power are corrected for temperature, humidity, and barometric pressure via manual entry of the parameters at the beginning of the test (altitude correction is not needed as it is accounted for when measuring barometric pressure).
- 2.6. Correction factors are calculated per SAE J1341.
- 2.7. Instruments used to measure temperature, humidity and barometric pressure are to be laboratory grade devices with accuracy (specified by the manufacturer) of at least $\pm 5\%$.
- 2.8. Instruments used to measure temperature, humidity and barometric pressure are to be calibrated within the last 12 months.
- 2.9. Temperature, humidity and barometric pressure are to be recorded before and after the test and the before and after numbers are recorded along with any torque or power data.

3. Level 3 System – Accuracy Bracket: $\pm 10\%$ of Full Scale

- 3.1. All conditions for above level 1 and 2 are met with the following exceptions and additions.
- 3.2. The dynamometer manufacturer specifies that the dynamometer used will measure speed, torque, and horsepower accurate to within $\pm \text{TBD}\%$ of full scale.
- 3.3. A cooling fan or blower is used to cool the vehicle.
 - 3.3.1. Velocity of cooling air is measured and repeated.

- 3.3.2. The size of cooling air duct will be such that the opening of the duct is one half of the size of the front “grill” area of the vehicle or greater.
- 3.4. Tie down straps are used and the force on each side of the tie down strap is measured ($\pm 5\%$ accuracy) and duplicated to within 5% .
- 3.5. Vehicle torque and/or power are corrected for temperature, humidity, and barometric pressure continuously during the test.
- 3.6. Instruments used to measure temperature, humidity and barometric pressure are to be laboratory grade devices with accuracy (specified by the manufacturer) of at least $\pm 1\%$.
- 3.7. Instruments used to measure temperature, humidity and barometric pressure are to be calibrated within the last 12 months or per manufacturer’s recommendation, whichever is shortest.
- 3.8. Temperature, humidity and barometric pressure are to be recorded before and after the test and the before and after numbers are reported along with any torque or power data.
- 3.9. The test is performed by a computer automated system which will assure that the test is performed in the same way each time. This is necessary to remove variances in test execution.

4. Level 4 System – Accuracy Bracket: $\pm 5\%$ of Full Scale

- 4.1. All conditions for above level 1, 2 and 3 are met with the following exceptions and additions.
- 4.2. The dynamometer manufacturer specifies that the dynamometer used will measure speed, torque, and horsepower accurate to within $\pm \text{TBD}\%$ of full scale.
- 4.3. Dynamometer has been calibrated per the above except within the last 24 hours.
- 4.4. Instruments used to measure temperature, humidity and barometric pressure are to be calibrated within the last 6 months or per manufacturer’s recommendation, whichever is shortest.
- 4.5. In comparison tests, fuel used is exactly the same for each test.
 - 4.5.1. This typically requires that the fuel be stored and drawn from in a container large enough so that no additional fuel needs to be added between tests.
- 4.6. Speed of the vehicle cooling blower will be controlled so that the speed of the cooling air matches the simulated speed of the vehicle to $\pm 10\%$.
- 4.7. Vehicle operating conditions are to be duplicated within $\pm 10\%$. This often means that these conditions must be controlled by some means. These include the following:
 - 4.7.1. Oil temperature
 - 4.7.2. Fuel temperature
 - 4.7.3. Engine coolant temperature
 - 4.7.4. Intake manifold temperature
 - 4.7.5. Under-hood temperature
 - 4.7.6. Transmission temperature
 - 4.7.7. Differential temperature

5. Level 5 System – Accuracy Bracket: $\pm 2\%$ of Full Scale

- 5.1. All conditions for above level 1, 2, 3 and 4 are met with the following exceptions and additions.

- 5.2. The dynamometer manufacturer specifies that the dynamometer used will measure speed, torque, and horsepower accurate to within \pm TBD% of full scale.
- 5.3. Combustion air is to be duplicated within \pm 5%. This often means that combustion air must be controlled by some means.
- 5.4. Dynamometer torque has been calibrated at 10 points and torque data has been linearized via a multi-order polynomial equation.