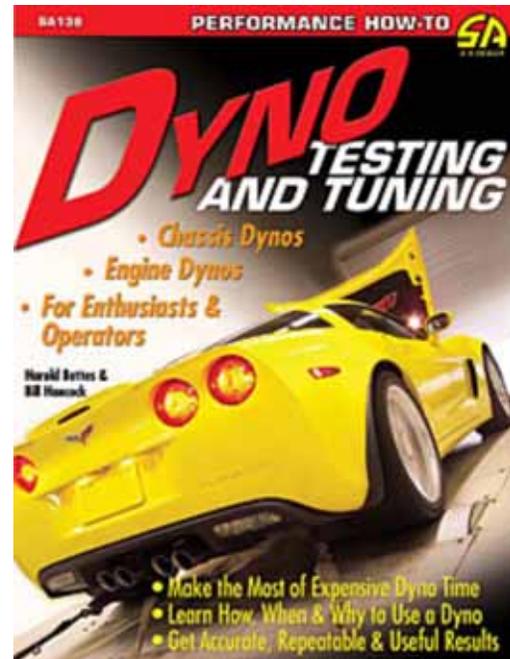


## Why the Horsepower Numbers Will Never Match

I have worked for SuperFlow commissioning new chassis dynos for 13 years<sup>1</sup>. During this time I have provided countless training sessions with customers who purchased SuperFlow products; read volumes of technical documentation, magazine articles and marketing hype; and endured the complaints of nearly every customer I ever met about why their dyno numbers don't match those from another dyno. In this document I explain this so you, the reader and new dyno owner, can think about how to handle this issue.

Take the information in the following paragraphs as my experienced opinion, mixed with words found on the Internet or from magazine sources. I try to identify those sections so as not to completely plagiarize what others have said, but in some cases, I simply do not know who the author was, so blame me and I'll assume credit for the information. Some of it is based on actual physical science, so I cannot take any credit for those sections—that stuff existed long before me.

A great book for any new dyno operator to read is *Dyno Testing and Tuning* by Harold Bettes and Bill Hancock. These two guys have over 50 years combined experience in the dyno business and offer some good general guidelines to help make the most of the business you are entering into. I make no money from the book sale and just think it is a good primer to read.



### What's the Difference between Your Dyno and a Dynojet?

In the chassis dyno world, Dynojet has the bulk of the market. They've been around the longest, are affordable, and are easy to use. But, do they produce real horsepower numbers bound by the laws of physics? Read on.

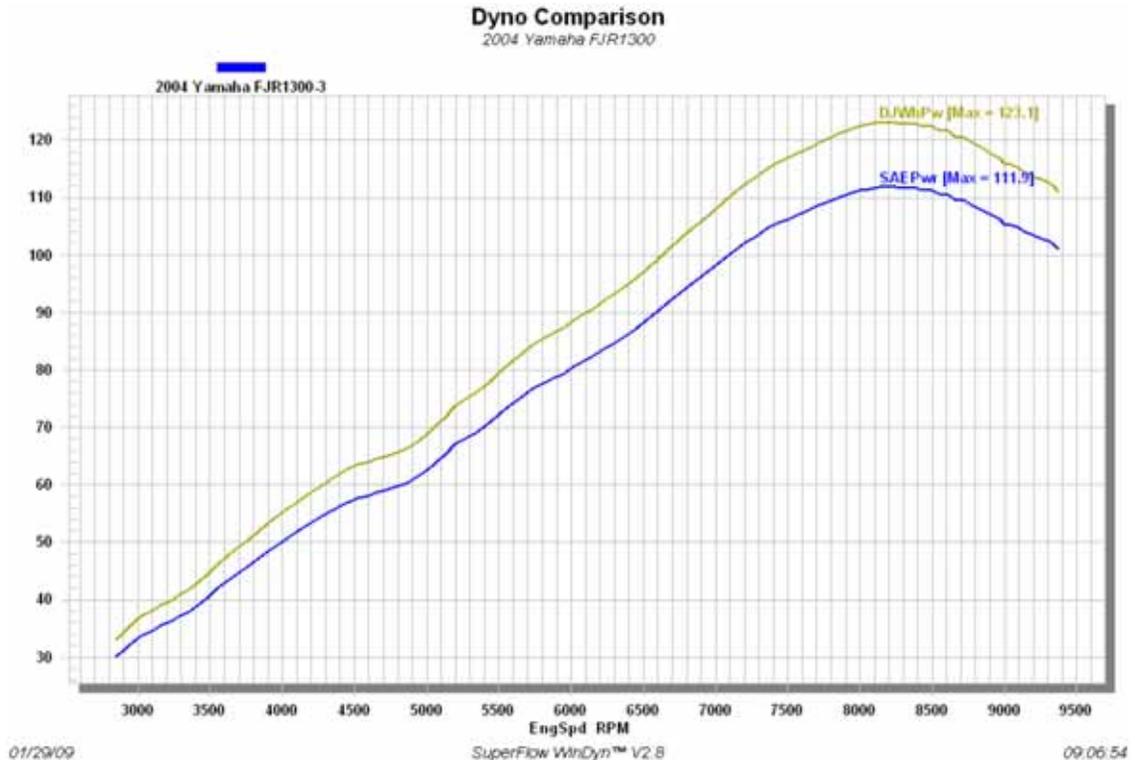
Since Dynojet is the most popular chassis dyno, many people compare the numbers they get from their dyno, regardless of type or brand, to those obtained from a Dynojet. It doesn't matter whether it is an inertia dyno or loaded dyno, motorcycle dyno or car dyno—Dynojet is still the most likely comparison you'll see. If you see chassis dyno numbers in a marketing brochure, a magazine article, or on the Internet, they most likely came from a Dynojet, or they've been manipulated to appear as if they came from a Dynojet.

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1. Written by Bret Williamson, SuperFlow Technical Support Engineer.

**Bottom line:** if you are using a dynamometer other than a Dynojet, your numbers will not match theirs. Period. End of discussion.

Wow, that's a pretty bold statement, Bret. Can you explain why? Yes, I think so. Some of this is going to be a little technical, but stay with me to the end, and hopefully it will all make sense.

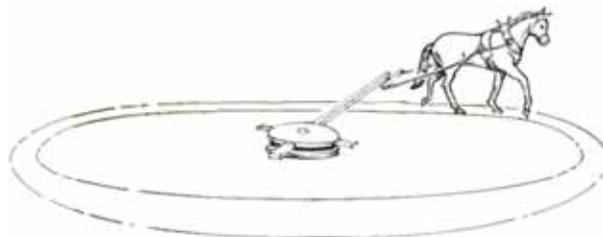


## How is Horsepower Determined?

Perhaps the first thing you need to understand is how horsepower is measured and what it is. First, it cannot be measured: it must be calculated. You can measure torque, revolutions per minute, and acceleration, but you cannot measure horsepower. No one can. It is always derived by measuring something else. Horsepower is the ability to accomplish a specific amount of work in a given amount of time, such as moving a race car down a quarter mile track in 10 seconds. Torque alone accomplishes no work—it is only a force. Thus, when a force (torque) is applied to an object and displacement of the object (movement) occurs, work is performed. Power, then, is the rate of performing work, expressed as the time derivative of work.

The physics behind this did not come from SuperFlow, Dynojet, or any other dyno manufacturer. It came from an inventor, James Watt. Please read about him here:

[http://en.wikipedia.org/wiki/James\\_Watt](http://en.wikipedia.org/wiki/James_Watt)



Mr. Watt wanted to sell steam-powered engines and needed a marketing scheme to convince the buyers how much more work the steam engine could do over the work of a team of horses. He was no different than you, as your dynamometer is a way to convince car or motorcycle owners you can give them more power to win races, impress friends, or simply boost their ego. Mr. Watt gave us the following equation:

$$\text{Horsepower} = \frac{\text{Torque} \times \text{RPM}}{5252}$$

Many of you probably want to know where the constant 5252 came from. The Internet has many links where you can read about this, so why rewrite it all here? Here's a great link to start with:

<http://en.wikipedia.org/wiki/Horsepower>

When you finish with that link, go here to read more:

[http://www.epi-eng.com/piston\\_engine\\_technology/power\\_and\\_torque.htm](http://www.epi-eng.com/piston_engine_technology/power_and_torque.htm)

I reproduce the explanation in this Web page at the end of this document. It is simply one of the best explanations I have ever found.

In simple terms, for those of you who do not want to read about it on the Internet, one horsepower is the ability to lift 550 pounds one foot in one second, or 33,000 pounds one foot in one minute. A few great athletes may be able to do that, but most of us cannot, so we rely on an engine to do it for us.

## How Does This Work on a Chassis Dyno?

Unfortunately, with most chassis dynos (those without in-line torque transducers), the math is a bit more complicated than what Mr. Watt gave us above. Generally, there are two types of chassis dynos:

- Those that can only measure a rate of acceleration of a known mass, sometimes called “inertia-only dynos” or “accelerometers”
- Those that can do the above, plus have some type of load device—usually an eddy current Power Absorption Unit (PAU) or fluid brake

Only a few chassis dynos can perform loaded tests, as they have no “rolls of mass” to accelerate.

What you need to understand is that the fundamental physics in all dynamometer types still must correlate to Mr. Watt's equation. It must be used in some form or another to compute the correct horsepower.

Let's examine the equations used in a SuperFlow chassis dynamometer. Afterward, ask yourself if you think these formulas should apply regardless of the dynamometer manufacturer. SuperFlow did not invent these equations; they are derived from Mr. Watt's equation and other basic physics fundamentals. The basic equation SuperFlow uses is:

$$\text{InertiaPower} + \text{DynoLosses} + \text{AbsorberPower} = \text{WheelPower}$$

The inertia power is nothing more than a measurement of acceleration, as in revolutions of the roll in a given amount of time. SuperFlow, as do other dyno manufacturers, must provide the software with a known value of equivalent inertia mass (in this case, the roll) which is derived through a very thorough process. In SuperFlow's case, the process was certified to use in the IM240 emission dynos we developed in the early 90s. For the most part, you simply must trust that these numbers are valid, as you really have no simple way to prove otherwise.

In an inertia only dyno, we must compute the force moving the rolls. An acceleration value is derived by comparing the velocity of the surface of the rolls from one revolution to another. SuperFlow does this comparison many times during one revolution to increase the accuracy of the acceleration measurement. Others (such as Dynojet) may only do this once per revolution.

After finding the acceleration value (in this case, miles per hour per second), power can be computed as:

$$\frac{\text{InertialMass} \times \text{Acceleration(inGs)} \times \text{RollSpeed}}{375}$$

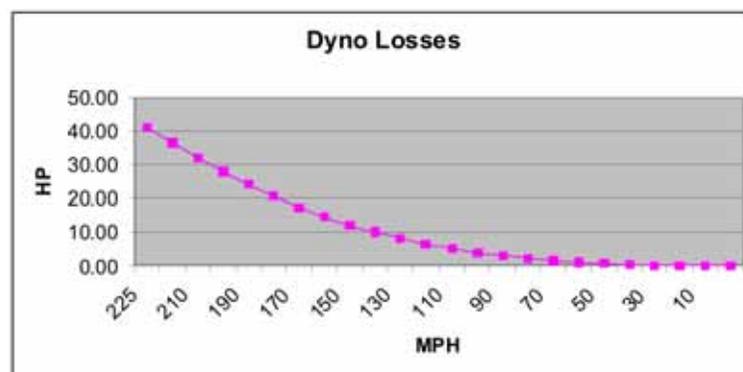
Using English units, the roll speed displays as miles per hour. The constant, 375, is a convenient way to convert units: 1 hp = 375 lbf times mph (taken from the Wikipedia link to horsepower mentioned above). The inertia times the acceleration portion of the equation is the force (torque) applied to the roll. Look hard enough, and you'll see Mr. Watt's equation in there.

Now how about dyno losses. What are these? Very simple: any time we rotate something, we use a little power doing so. Nothing is friction free, and certainly not the dynamometer rolls. Frictional losses occur when rotating in their bearings. Windage losses occur as they spin through the air. These losses consume some of the vehicle power applied to the rolls during the test. To properly compute power applied to the rolls, we must add this lost power to the inertia power calculated previously. SuperFlow determines these losses at the factory. The values are embedded in the software, and a lookup function is used to add them back into the power equation during any type of test. Other dyno manufacturers must do the same.

How do you know the loss values being used are accurate? SuperFlow provides a calibration sheet with every chassis dynamometer it sells. I cannot speak for other manufacturers, but they must add back in parasitic loss data, or else the power numbers produced when testing a vehicle will be incorrect. Here is SuperFlow's formula:

$$(\text{InterpolateRollSpeedToLookupTableHP}) \times \text{CurrentAirDensity}$$

The air density portion is necessary for correct windage loss computations. The lookup table looks like this:



So, for any given speed in mph, a horsepower value is looked up on the table and added to the power derived through acceleration (inertia power).

Now let's look at the last part of the equation: *absorber power*. This portion of the equation is used only if the dyno has a PAU attached so it can apply load. Part of the PAU includes a device called a strain gauge which provides an electrical means of measuring a force—in this case, torque. This is a real, indisputable measurement of exerted force. The dyno manufacturer normally provides a

means to precisely calibrate this device using some certified weights and a calibration arm of specific length. SuperFlow does.

The formula is quite simple, as it resembles Mr. Watt's equation with only slight variations. Since the power is exerted at the roll, the equation must use its torque and rpm references at the roll, not at the engine. Thus, the equation looks like this:

$$\frac{\text{RollTorque} \times \text{RollRPM}}{5252}$$

There is no need to measure engine rpm because we are only concerned with the revolutions of the roll. This is why obtaining wheel power figures from a chassis dynamometer does not require the operator to hook up a device to obtain engine rpm. It simply isn't necessary in any of the wheel power formulas.

That's it—the calculations we use to compute wheel horsepower are no longer a secret. Those of you content with knowing this information may now stop reading and use your dynamometer for its intended purpose—to provide a baseline and evaluate changes to the vehicle and their impact to that baseline. For those of you who live and die by the numbers, read on.



## The “Zen of Inertia” by Mark Dobeck

In 1985, the Dynojet dynamometer became a product for anyone to purchase. Dynojet founder Mark Dobeck decided everyone could benefit by having a chassis dynamometer, so he set out to build and sell them. Much like Mr. Watt, he had other motives: he needed a way to prove his jet kits worked so he could sell more of them. Mr. Dobeck succeeded in producing and selling a chassis dynamometer and has long ago sold off his interests in the company. He gave an interview to *Sports Car International* that was published in March 2006. The most revealing part of that interview is extracted here for your entertainment and understanding:

“One of the biggest headaches of Dynojet's go-it-alone chassis dyno project was figuring out how to assign meaningful power numbers in the face of unknown inertia from the moving parts of hundreds or thousands of engine, drivetrain and tire combinations.

Wrestling to fully understand inertia and powertrain losses, Dobeck and his team quickly realized that the standard physics formula of weight, time and distance for converting acceleration into horsepower simply didn't work right. Even after eliminating all drivetrain losses and attempting to account for all heat loss in the vehicle and dyno systems, the derived number was always lower than accepted numbers.

The Dynojet team poured on resources and burned up time and money investigating the Mystery of the Missing Power. But no matter what it did, the mathematics never added up.

Dynojet's final number fudge—which would eventually be applied to every vehicle strapped to a Dynojet chassis dyno—was arbitrarily based on a number from the most powerful road-going motorcycle of the time, a 1985 1200-cc Yamaha VMax. The VMax had 145 advertised factory horsepower, which was far above the raw 90 horsepower number spit out by the formula. Meanwhile, existing aftermarket torque-cell engine dynamometers delivered numbers that clustered around 120.

Always a pragmatist, Dobeck finally ordered his chief engineer to doctor the math so that the Dynojet 100 measured 120 horsepower for a stock VMax. And that was that: for once and forever, the power of everything else in the world would be relative to a 1985 Yamaha VMax and a fudged imaginary number that was close to the 'agreement reality' of the average of some other imaginary numbers.

Dobeck's engineering staff was dismayed by the decision. But the Dynojet 100 measured surplus power available to accelerate the vehicle' mass—no more, no less—and that was true even if the power modification was a low-inertia flywheel or lightweight wheels. As long as the inertial dyno's numbers were repeatable, the critical question of whether a particular mode make the engine accelerate faster or slower would be answered correctly.”

Dobeck then began selling the new “bogus meter” to dealers all across the USA. But whether the numbers were right or not didn't matter, because at that time, his was the only game in town, and no one knew differently. Again, if the dyno was used to provide a baseline and then evaluate how a change to the vehicle impacted that baseline, it worked great!

So what does the “imaginary number” Dynojet employs mean if you do not have a Dynojet dyno? In the article above, if you do the math, it appears Dobeck manipulated the numbers by as much as 33%. It simply means your numbers will never match those produced by a Dynojet. Period. End of story. That’s because Mark Dobeck and his team of engineers changed the laws of physics. So stop trying to make the comparison.

Ah, but there are many Dynojet dynos in the marketplace, so the comparison is inevitable. Some *current* estimates of the difference range from 5% all the way to 21% over true rear-wheel horsepower and anywhere in between. Some even believe it is a sliding scale, based on horsepower or speed of the vehicle. Try to get the actual formula from Dynojet, and they will give you their “it’s proprietary” rhetoric.

Regardless, it is simply not a real number, but a Dynojet number, and should be referred to as such. The horsepower terminology should now include a term called DJHP to indicate the numbers were derived from a Dynojet machine and cannot be duplicated on anything other than another similar Dynojet machine.

In a sense, the imaginary number created by Dynojet has ruined this industry but certainly has been a boon for them. The consumer of dyno services is often only interested in an ego-boosting figure, and the Dynojet certainly delivers on that aspect. The other manufacturers are forced to supply additional power calculations to attempt to “match” the magic number derived from a Dynojet.

SuperFlow's WinDyn™ software easily allows for this, and we encourage customers to use these figures if their market insists upon it (most do). We default the imaginary number to 10% (a multiplier of 1.10 to the standard SAEPwr number) based on feedback from our customers who make comparisons to Dynojets, but it can be adjusted to suit your market if necessary. We identify the resultant numbers as DJWhPw and DJWhTq, separate from the real SAEPwr and SAETrq numbers that have no magic applied to them. Take a look at the graph on page 2 of this document for an example.

Nevertheless, I have heard the same story over and over: “But I just want to give my customers the real numbers—no bull.” I admire your integrity, but in most cases, you won’t sell any dyno time to your market. It is because the customers simply do not understand what has been going on for over 25 years. Sure, you can try to educate them, and we encourage that, but that gets old over time; for most, it’s just easier to give them the ego-boosting numbers they expect and take their money.

By the way, it may interest you to know that even though SuperFlow can provide the real numbers and the imaginary numbers on the same printout if desired, as of this writing, a Dynojet dyno cannot. That’s because there is no way to obtain a true horsepower number that follows the laws of physics from a Dynojet.

## What about Correction Factors?

The term *correction factor*, when spoken in conjunction with dynamometer testing, refers to atmospheric correction multipliers applied to the raw horsepower and torque values. This is done due to an internal combustion engine's voracious appetite for oxygen molecules. As air density changes due to barometric pressure, water vapor, and temperature, the number of oxygen molecules available in each gulp taken by the engine changes, as does its output power. Higher air density, which allows more fuel to be added, will subsequently allow the engine to produce more horsepower. Lower air density results in the reverse effect.

Therefore, engineers have devised a way to apply a multiplier to raw power numbers to produce estimated power values as if the engine were tested in a "perfect" atmosphere. Unfortunately, having only one such correction factor simply isn't enough, so we have lots of these things. And in some cases, we have variations on the same theme.

The standard bearers in the USA are the Society of Automotive Engineers (SAE). To learn more about these folks, start by going here:

<http://www.sae.org/servlets/index>

In general, two common standards are used in the USA, with more standards used in other parts of the world. The current USA standard is J1349 (usually referred to as SAEPwr by most dyno companies) which became the standard in 1984. It superseded the older standard J607 (usually referred to as STPPwr or STDPwr) which was created in 1956 and last revised in 1974. The OEMs and motorcycle performance industry generally use the J1349 standard. SuperFlow defaults to this standard on its CycleDyn. Most of the automotive performance industry in the USA use the old J607 standard. As such, SuperFlow defaults to this standard on all its AutoDyn products.

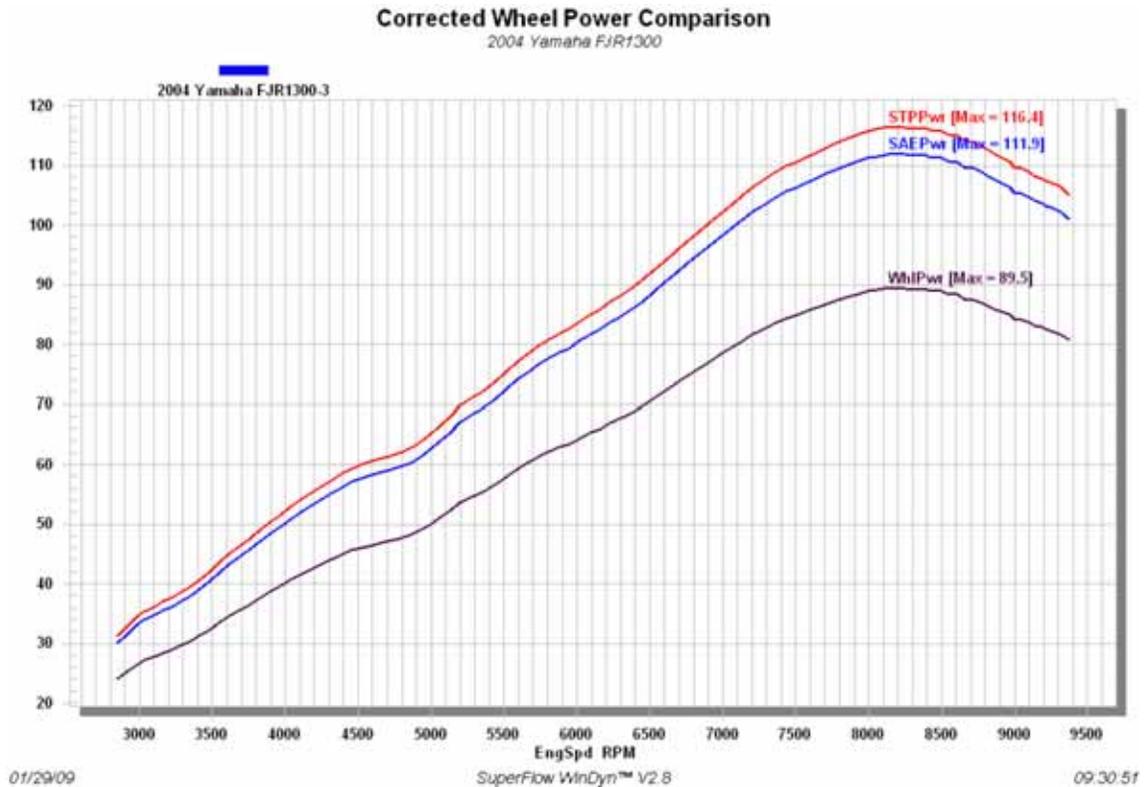
So, what is the difference and why should you care? The two standards use a different barometric pressure reference (J1349 assumes ~800 foot altitude; J607 assumes sea level). They also use a different temperature reference (J1349 uses 77 degrees F; J607 uses 60 degrees F). They both use dry air for a reference.

Okay, what does this mean to you? Generally, the correction multiplier for the J607 standard will be ~4–5% greater than the J1349 multiplier. So, let's assume the raw uncorrected power of the vehicle is 100 hp, and the atmospheric conditions create a J1349 multiplier of 1.00. The J1349 corrected horsepower will be  $100 \times 1.00 = 100$  CHp. Those same conditions will create a J607 multiplier of ~1.04 which will result in a corrected horsepower value of  $100 \times 1.04 = 104$  CHp. Take your pick. Both are equally correct with no fudge factor applied to either one. It is just two different, accepted multipliers.

In the example graph below from a 2004 Yamaha FJR1300 motorcycle tested on a CycleDyn in Colorado Springs, the numbers looked like this:

- Uncorrected HP = 89.5 Hp (WhlPwr)
- J1349 corrected HP = 111.9 CHp (SAEPwr)
- J607 (STPPwr) corrected HP = 116.4 CHp (SAEPwr)

The J1349 multiplier was 1.25 and the J607 multiplier was 1.30—both very high due to the high altitude and low air density in Colorado Springs.



By the way, in the example above, the correction factor was greater than 1.00 in both cases, and that may generally be the case where you are testing. However, if you live close to sea level or are testing in very cold, dense air, the uncorrected wheel power numbers may actually be higher than those given after applying the correction factor.

In such a case, the correction multiplier would be less than 1.00—perhaps .98 or .99. We see this routinely in places like Daytona Beach in the spring time before it gets hot and humid. So, don't be alarmed if the corrected numbers are lower than the uncorrected numbers. It just pays to investigate why.

One last note about correction factors: according to the SAE J1349 standard, any test conducted where the atmospheric correction exceeds 3% shall be noted as a nonstandard test. In the performance world, no one does this. What does it mean? The data obtained for the FJR1300 above is considered invalid by the SAE and should not be considered as gospel.

## What about Friction Factors and Mechanical Efficiency?

This question stems from the section in the SAE document that discusses how to account for the frictional power consumed by the *engine* and whether we should apply an atmospheric correction to that power as well as the measured brake power.

The answer is “yes” when testing the engine on an engine dynamometer. The SAE provides several means for doing this, one of which is to basically estimate the mechanical efficiency of the engine to be ~85%; another is to actually measure the frictional losses within the engine and then add those back to the measured power before applying the correction multiplier, then subtract the frictional losses. The idea here is to apply an atmospheric correction to the total power made at the engine, not just what was left over and measured at the brake.

Engine dynos make this type of correction. More sophisticated ones have a motoring capability to motor the engine (without it running) to actually measure the frictional losses within the engine. For chassis dynos, this is not practical and would be enormously expensive to achieve, so it just isn't done.

In fact, on a SuperFlow chassis dyno, no assumption of mechanical efficiency is made at all. Since we are measuring power at the rear wheels, we do not need or care to know anything about the mechanical losses because what we really want to know is exactly what power we have at the roll surface to accelerate the vehicle. Since we are not measuring the power at the engine, we cannot begin to assume what its frictional losses are, so we ignore them. The SAE standards do not reflect a process or procedure to do otherwise.

What does Dynojet assume for frictional losses? In their older manuals where they discussed correction factors, the equation they referenced used the SAE 85% mechanical efficiency formula. Thus, if they are still using that method for computing the correction factor, their multiplier will be higher than that used by a SuperFlow system which does not apply any mechanical efficiency factor.

It is strange they should choose to do this, since the SAE paper discusses how this is rational for use on an engine. But the power at the roll on the chassis dyno is already missing some engine power consumed through the vehicle drivetrain. So, unless they are somehow figuring out the engine's horsepower, applying the correction formula, then subtracting back out the drivetrain losses, their method is certainly in error.

The end result is that the correction multiplier on a Dynojet manipulated by a frictional factor results in a higher multiplier than what is correct. So, the ego is stroked even more as the resulting *corrected* wheel power numbers end up higher on paper.

## Does Vehicle Inertia matter?

On a chassis dyno with large rolls to accelerate, we are concerned with the inertia of those rolls, as that figure is used in the force calculation to obtain a power number. The dyno manufacturer provides the system with a precise value of the dyno's inertia, but what about the inertia of the vehicle—particularly that of the rotating parts sitting on top of the rolls?

In the inertia system of a chassis dyno, the wheels, tires, brakes, etc., on top of the rolls do indeed have an effect on the outcome of the acceleration style test. The rotating mass of those items should be part of the overall force calculation. Or should it?

On simple inertial dynamometers, some (most) companies use an average for the inertial mass value of the engine, transmission, driveshaft, axles, and rear wheels. This is saying that a 4-cylinder, 2.0 ltr. Porsche 914 has the same rotating mass and same rear wheels as an 8-cylinder, 5.0 ltr. Porsche 928 S+4. This simply is not true and is also wrong.

First, it is very difficult for the dyno operator to precisely determine the value of the vehicle's rotating inertial mass. Because of this, most dyno manufacturers ignore it completely or add an estimated value that is unalterable by the operator regardless of vehicle size or type.

The effect of this inertia is seen in several ways. Let's assume the vehicle's true rotating inertia is 150 lbs. (a simplification of units, but bear with me). The dyno software assumes 0 lbs. The operator performs a rapid acceleration test and obtains an uncorrected power number of 400 hp and then performs a steady-state test where peak power is made and sees 450 hp. Obviously, the results show a difference of 50 hp.

Now we go back into the software and tell the dyno there's an additional 150 lbs. of inertia to consider instead of zero. We re-run the rapid acceleration test and now get 450 hp (this will never happen exactly, but assume it will for argument's sake). The steady-state test is also re-run, and

we get the same 450 hp. We see a 50-hp difference on the accel test data, but no difference on the steady-state test data.

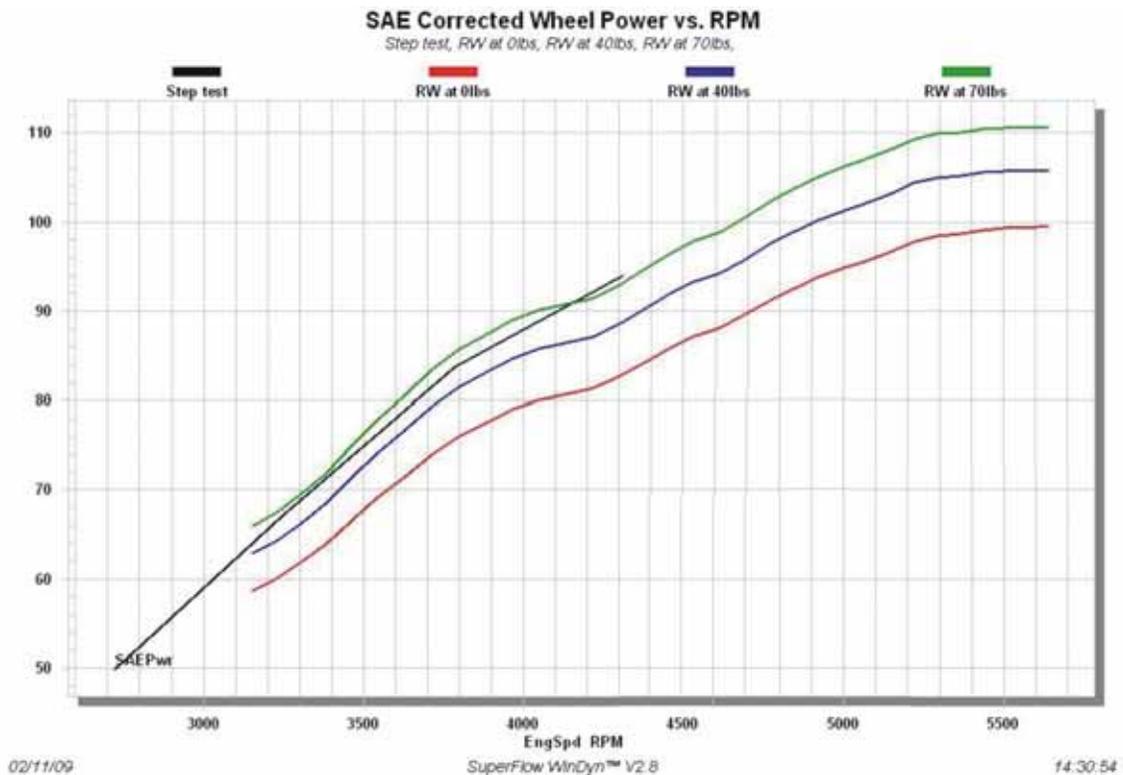
Why the difference? Because on the steady-state test, the inertia of the system and the vehicle doesn't make any difference because the acceleration rate is zero. But telling the system we added 150 lbs. makes a significant difference to the acceleration test data, as it should.

So why ignore this inertia or set it to a fixed value? As you can see, it has an effect any time we test in the acceleration mode, so why not accommodate for it? We can and sometimes do. SuperFlow defaults the CycleDYN systems to 40 lbs. and AutoDYN to 0.

Can we precisely measure it? Not easily, and not without considerable time and expense—two things contrary to the use of chassis dynos. I cannot speak to what the other dyno manufacturers such as Dynojet are doing because they do not tell the end user. SuperFlow at least provides the user with information about what we are doing and allows the dyno operator to decide how to deal with this real inertia.

So, what if we ignore it and leave the system defaulted? That is absolutely fine, providing you are using the dyno as a tool to compare *your results to your results*. However, as you can see above, once you start altering the equation or compare results to another dyno system where you have no idea what value they are using for this inertia, you will get different results. Apples to oranges, as the saying goes.

This inertia phenomena is why testing a vehicle with different wheels and tires will result in different power numbers when performing acceleration type tests. If you perform steady-state tests, the numbers will not change, but few people choose to do that.



In the example above, we show the effects of “estimating” vehicle inertia. These tests were performed on a V-Twin motorcycle with a large 280-mm rear wheel mounted. The red, blue, and green lines represent a rapid inertial type sweep test approximately 3.5 seconds in duration. The

red line shows a power number where the dyno was told the vehicle inertia is 0 (pretty low number, but real nonetheless). Tell the dyno the rear wheel inertia is near 40 lbs., and you get the blue line. Tell the dyno the wheel inertia is 70 lbs., and you get the green line.

Run a steady-state step mode test, taking the inertia completely out of the equation, and you get real power numbers indicated by the black line (the test was cut short due to the engine overheating). So, in this case, if the dyno were told the wheel inertia was between 65–70 pounds, our rapid sweep test data might come close to real numbers. Alas, most dynos simply use a fixed vehicle inertia.

Try this simple scenario, one which has occurred many times: a motorcycle is tested with one type of wheel and tire combo. A month later, the exact same motorcycle is tested, but it has a new tire. Let's assume the new tire has a slightly smaller diameter than the old tire and actually weighs less than the old tire. Guess what—you will get slightly different power numbers. The smaller, lighter tire will allow the vehicle to accelerate quicker. Thus, the dyno will show more power on the accel test data.

I believe more than one motorcycle magazine has tested this theory and found it alarmingly true. I can tell you more than one professional motocross team has gotten caught up in this phenomenon as well. It affects the car guys just the same.

So, this one single item—an assumption of the vehicle inertia—throws a HUGE monkey wrench into your ability to compare test data results from one dynamometer to another. The SAE provides no standard whatsoever on how a test instrument is supposed to deal with this issue. The dyno makers are free to handle it in whatever way they choose. Those who assume a large inertia value and default it as a constant give you bigger hp numbers. It's as simple as that.

Keep that in mind when you test your sport compact and compare its numbers to the diesel truck. Chances are, the sport compact's accel numbers are inflated and the diesel truck's are lower than they should be. Want to know the real answer? Steady-state both! Then the inertia doesn't matter.

That's right—since the acceleration rate is zero, any system or vehicle inertia cancels out. It doesn't matter. So, if you really want to know the true amount of horsepower the vehicle is putting to the ground, steady-state it at various points through its power band and then plot a curve through those points. As long as the dyno's strain gauge is properly calibrated, the power numbers will be correct.



“Appendix 1: Derivation of the Power Equation” on page 18 shows a series of graphs depicting the effects of changing a tire on a particular motorcycle. Please review each graph and read the material for a great explanation as to what happens.

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## Sweep Testing vs. Steady-State: Which is better?

Most dyno software assumes all vehicles have the same rotating mass (they don't), and disregarding that fact is a good reason why the power numbers can be different. The most accurate measurement of rear wheel horsepower is in steady-state mode (inertia is not a factor in the power equation.) Any change in the inertial mass affects the inertia power result, but not the true, rear wheel horsepower.

On a chassis dyno, what can inflate power readings but not really make more engine power in the real world? Changing to light, worn race rear tires will improve power output on an inertia dyno but not improve real-world top speed. A heavier, brand-new street tire replacing the light, worn tire will decrease measured power on an inertia dyno but not decrease real-world top speed.

The lighter wheels are a good thing, as you'll get better acceleration in lower gears, especially 1st and 2nd (accelerating less inertial mass). Better handling is also possible. However, driving on worn, light tires is foolish, and I am certainly not recommending it.

Proper tuning, especially on highly modified engines, can greatly affect the power difference. Since a Dynojet inertia dyno sweeps so quickly on acceleration tests, it is nearly impossible to properly tune a fuel map on an injected engine.

A sweep test (hold the throttle wide open and sweep from low rpm to high rpm) will often trigger the acceleration fuel map along with the main fuel map, causing the fuel mixture readings to indicate the motor is overly rich. This causes the tuner to lean out the main fuel map. Of course, in the real world, in the upper gears, the acceleration rate of the engine is much slower than what they tested at, so it doesn't trigger the acceleration fuel map and the engine ends up a lot leaner in reality.

So, what should you do? Tune the full throttle map in real-world scenarios at a drag strip (to best trap speed) or in steady-state mode on a dyno capable of performing such a test.

You have a choice: optimize tuning for a Dynojet inertia type dyno and make big numbers, or tune the engine to make the best power under load on a load-bearing dyno and blow off the big DJ dyno numbers.

Can a tuner cheat and make a load-bearing dyno read higher? Perhaps, as any dyno can be incorrectly calibrated. Keep in mind, sweep tests are the least reliable of all tests—there is *no* question about that. Since the rotating mass of the vehicle is a variable in a sweep test (not in a steady-state test), the actual inertia factor entered affects the final power figure. Tell the software that the vehicle has a lot of rotating mass to accelerate, and the power number increases.

So, if you want true horsepower, you must use a steady-state test mode. Then the inertial mass makes no difference. Given a proper load cell calibration on the dyno, you will get an accurate power reading.

Are optimal final tuning settings different on an inertia dyno versus a load-bearing dyno? For many reasons, final tune settings are different and, since most load bearing dynos will perform both types of tests, you can easily see what the results are. Most good tuners will choose the steady-state test over a sweep test.

Without a doubt, the steady-state test mode is the most consistently superior method of tuning—anybody who has the capability to do it will echo that sentiment. It's only an arguable point with those who can't do it properly.

One other point: different rates of acceleration will result in different power numbers. Take a look at the graph below. Although the tests were performed on an engine dyno, the same results will occur on a chassis dyno or different chassis dynos if the rate of acceleration is different due to different inertia in the dyno rolls or vehicle.



In the graph above, the black line is a 500-rpm step test. It makes the most power, from 3,000 to 5,500 rpm.

The blue line was a 600 rpm-sec test from 3,000 to 5,500 rpm. It makes the least power.

The red and green lines were both run at 300 rpm/sec., 3,000 to 5,500 rpm. Now how well they overlay. That is good because it represents what we want the dyno to do for us: repeat, repeat, repeat. If it does that, it is a useful tool.

## Will My Chassis Dyno tell me about Crankshaft Power?

A common discussion is what factor can be applied to rear-wheel horsepower to reflect crankshaft horsepower.

A dynamometer can only measure actual power at the output location. Actual power produced and delivered by an engine will be highest if measured at the crankshaft, lower at the transmission output shaft, and even lower (but more meaningful) at the rear wheels. The power you use is the power at the rear wheels.

Some dynamometer companies add an estimated driveline loss factor to measured rear-wheel power readings in an attempt to give you an engine power number. The problem is: under what power conditions does this estimate come from? A small engine, a large engine, under coasting conditions, with a 185/70/15 radial tire or 335/35/18 radial tire? Did they use a new heavy radial tire or a worn, old, light racing tire?

Some companies make a concerted effort to measure frictional losses and optionally add the power to the measured readings. Other companies say it's not important and provide a blanket single factor for frictional losses. Some say there is a meaningful "average" for every car (4-stroke/4-cylinder/4-speed transmission or 4-stroke/8-cylinder/automatic transmission) and apply it to every car because they say it is not a significant difference.

Blanket estimates of "average" losses and corrections are incorrect. In short, there is *no* meaningful average estimated value to get a power loss measurement for all vehicles. So obviously, unless they actually measure the power lost in the driveline under driven load conditions, *no* dyno company can accurately *predict* engine power from a chassis dyno.

It's expensive to measure frictional losses in the engine and drivetrain, requiring the dyno to drive the vehicle with the engine off. Add the cost of a 100+hp electric motor, controlled power supply, etc., and it is not likely that a \$20,000 dyno will be equipped with that level of equipment.

SuperFlow offers a feature (as do others) in which a coast-down test can be performed after the acceleration portion of the test; then this coast-down data is re-applied to the acceleration data in an attempt to predict engine power. In essence, we are adding in measured driveline losses to measured wheel power in an effort to predict engine power. The problem with this method is it still requires the user to enter a variable to "adjust" the coast-down loss data to what is assumed to be the true losses when under load and accelerating. It also requires a close estimate of wheel inertia, something we discussed previously.

Since some companies are adding varying amounts of power to the actual "true" amount of power delivered and measured at the surface of the drive roller, this makes it an onerous task to compare power figures from different brands of dynamometer systems unless you know specifically where the numbers are coming from. SuperFlow systems allow the user to fully decipher any and all the math being used, so for anyone questioning the numbers, it can all be analyzed and justified.

True, rear-wheel horsepower is the standard of measuring the power that is actually delivered to the rear wheels. It is honest, true, fair, and duplicable and is the *only* standard that can be duplicated by the entire industry, regardless of the dyno manufacturer.

From my experience and that of many others, when comparing true, rear-wheel horsepower to Dynojet, you must apply a factor. As stated before, it appears this is a sliding scale based on horsepower, but the best estimate is 1.05 to 1.21 (maybe higher).

What this means for those of you trying to calculate what your crankshaft horsepower is based on Dynojet power numbers who are adding a 15% driveline efficiency loss, you are actually doubling (at least) the factor between the true rear-wheel power number and the crankshaft number.

Why? Because Dynojet already has a puff number added into their power numbers. Let's say the Dynojet number shows 200 hp and then you add another 15 percent. You get 230 crankshaft horsepower. You most likely now have a number much higher than the engine power number from the manufacturer.

So what about crankshaft horsepower vs. true rear-wheel horsepower? Because each vehicle is different, the best way is to dyno the engine and then dyno the vehicle to see exactly what the loss is. Remember, too, that unless you dyno your engine, you are only likely to get a crankshaft number from the manufacturer, and that's probably a "good" one that the marketing department is providing.

For those manufacturers that use Dynojet horsepower as proof of their claims, can you imagine the shock your customers receive when the horsepower number of a vehicle tested on a load-bearing dyno do not come close to their claim?

You want crankshaft power? Dyno the engine on an engine dynamometer. A chassis dyno is the wrong tool for that job.



## Okay, so now what do I do?

Chassis dyno horsepower—what is it? What to call it? Dynojet horsepower = **DJHP**. It's not really proper to call DJHP true rear-wheel horsepower, as neither the Mustang, Dynojet, Fuchs, SuperFlow, or Land and Sea dyno's will necessarily produce the same numbers as a Dynojet dyno, except by luck.

The whole idea of true rear-wheel horsepower is that *every* dyno manufacturer has the capability to provide those numbers. The SuperFlow chassis dynos, the Mustang, and Land and Sea are all capable of measuring power in steady-state mode and producing the same numbers—they all measure torque.

$$\frac{\text{Torque} \times \text{rpm}}{5252} = \text{Horsepower}$$

We've not diddled with physics. The only factor added to the measured reading in true rear-wheel horsepower is the additional energy (dyno parasitics) required to spin the roller to whatever speed—logical, proper, and required value for the measuring instrument. Thus, we have:

$$\frac{\text{Torque} \times \text{rpm}}{5252} = \text{Horsepower} + \text{ParasiticPower} = \text{TrueRearHorsepower}$$

Learn to use your dyno as a tool. That it what it is, regardless of who makes it. If it repeats well, it is a good tool. Learn how to keep it calibrated and how to use it when tuning an engine. Also learn which methods of testing work best for your applications and how to interpret the data. Have the company who sold you the dyno provide on-site training. Read the manual and research topics of interest on the Internet.



Give this document to all your customers to read. Give it to the sanctioning bodies who succumb to Dynojet's rhetoric and offer of a free dyno. Help them understand this market. Help them understand and appreciate the numbers you give them and the service you provide. Be part of the solution. Or, buy an **Easy** button, give them a line of bull and some bogus numbers, and be part of the problem. Let's call a spade a spade, and call Dynojet horsepower figures what they are: DJHP—not true, rear-wheel horsepower or anything remotely close to that.

Remember, there are no dyno police, so anybody operating or selling a dyno can produce any numbers they want without repercussion. Dynojet has proven this to be true for over 20 years, and they have the biggest share of the market for doing so.

Happy dynoing!



## Appendix 1: Derivation of the Power Equation

Taken from:

[http://www.epi-eng.com/piston\\_engine\\_technology/power\\_and\\_torque.htm#equation](http://www.epi-eng.com/piston_engine_technology/power_and_torque.htm#equation)

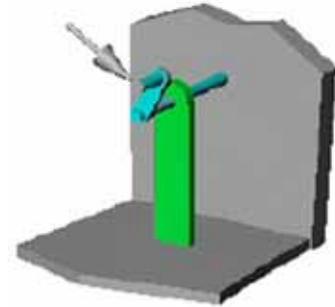
This part may not interest most readers, but several people have asked, "Okay, if

**Horsepower =  $\frac{\text{Torque} \times \text{rpm}}{5252}$** , then where does the **5252** come from?"

Here is the answer:

By definition: **Power =  $\frac{\text{Force} \times \text{Distance}}{\text{Time}}$**

Using the example in the figure to the right, when a constant tangential force of 100 pounds is applied to the 12" handle rotating at 2000 rpm, we know the force involved; so to calculate power, we need the distance the handle travels per unit time, expressed as:



$$\text{Power} = 100\text{Pounds} \times \text{DistancePerMinute}$$

Okay, how far does the crank handle move in one minute?

First, determine the distance it moves in one revolution:

$$\text{DistancePerRevolution} = 2 \times \pi \times \text{Radius}$$

$$\text{DistancePerRevolution} = 2 \times 3.1416 \times 1\text{Ft} = 6.283\text{Ft}$$

Now we know how far the crank moves in one revolution. How far does the crank move in one minute?

$$\text{DistancePerMinute} = 6.283\text{FtPerRev} \times 2000\text{RevPerMin} = 12,566\text{FtPerMinute}$$

Now we know enough to calculate the power, defined as: **Power =  $\frac{\text{Force} \times \text{Distance}}{\text{Time}}$**

$$\text{So: Power} = 100\text{Lbs} \times 12,566\text{FtPerMinute} = 1,256,600\text{LbFtPerMinute}$$

Swell, but how about *horsepower*? Remember that one horsepower is defined as 33000 pounds-foot of work per minute. Therefore:

$$\text{Horsepower} = \frac{\text{Power(LbFtPerMin)}}{33,000}$$

We already calculated that the power being applied to the crank wheel above is 1,256,600 lb•ft per minute. How many HP is that?

$$\text{Horsepower} = \frac{1,256,600}{33,000} = 38.1\text{HP}$$

Now we combine some information we already know to produce the magic **5252**. We already know that:

$$\text{Torque} = \text{Force} \times \text{Radius}$$

If we do a little algebraic manipulation and divide both sides of that equation by **Radius**, we get:

$$\text{A) Force} = \frac{\text{Torque}}{\text{Radius}}$$

Now, if **Distance** per revolution =  $\text{Radius} \times 2 \times \text{TT}$ , then:

$$\text{B) DistancePerMinute} = \text{Radius} \times 2 \times \text{TT} \times \text{rpm}$$

We already know:

$$\text{C) Power} = \text{Force} \times \text{DistancePerMinute}$$

So, if we plug the equivalent for **FORCE** from equation **A** and **DISTANCE per minute** from equation **B** into equation **C**, we get:

$$\text{Power} = \frac{\text{Torque}}{\text{Radius}} \times (\text{rpm} \times \text{Radius} \times 2 \times \text{TT})$$

Divide both sides by **33,000** to find **HP**:  $\text{HP} = \frac{\text{Torque}}{\text{Radius}} \times \frac{(\text{rpm} \times \text{Radius} \times 2 \times \text{tt})}{33,000}$

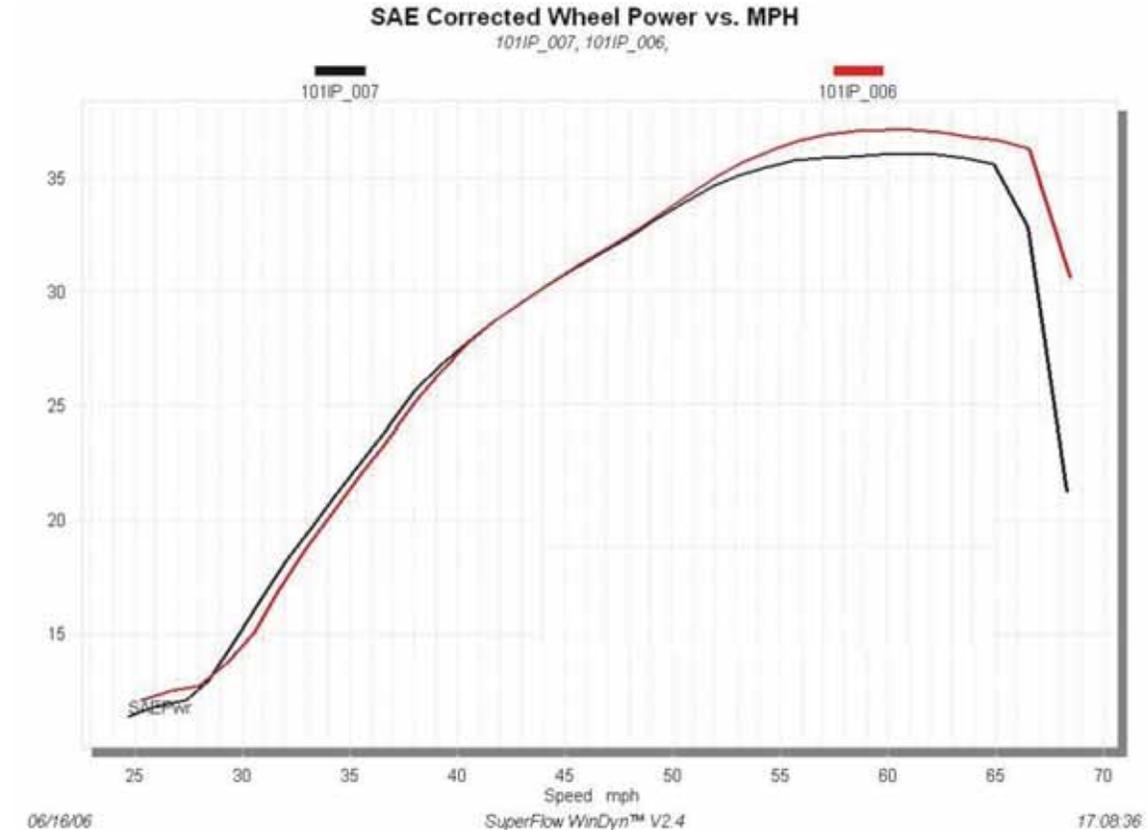
By reducing, we get:  $\text{HP} = \frac{\text{Torque} \times \text{rpm} \times 6.28}{33,000}$

Since:  $\frac{33,000}{6.2832} = 5252$

Therefore:  $\text{HP} = \frac{\text{Torque} \times \text{rpm}}{5252}$

Note that at 5252 rpm, torque and hp are equal. At any rpm below 5252, the value of torque is greater than the value of hp; above 5252 rpm, the value of torque is less than the value of hp.

## Appendix 2: Differences Caused by a New Rear Tire



This is a very good comparison chart demonstrating how a change to a different wheel and tire on a motorcycle can affect the power measured. In this case, test 6 was an inertia run with a 25.6" Kenda tire that was pretty worn out.

Test 7 was an inertial test performed after a tire and wheel change. The new tire was a 25.2" Dunlop tire. The operator assumed the tire/wheel weights and diameters were the same, but in fact, they were quite different. The tire/wheel combination used in test 7 was heavier and shorter than the combination used in test 6. Thus, the wheel inertia was different, causing a different rate of acceleration during the inertia test. This resulted in lower power at the end of the test, when the wheel inertia has a greater effect due to increased speed.

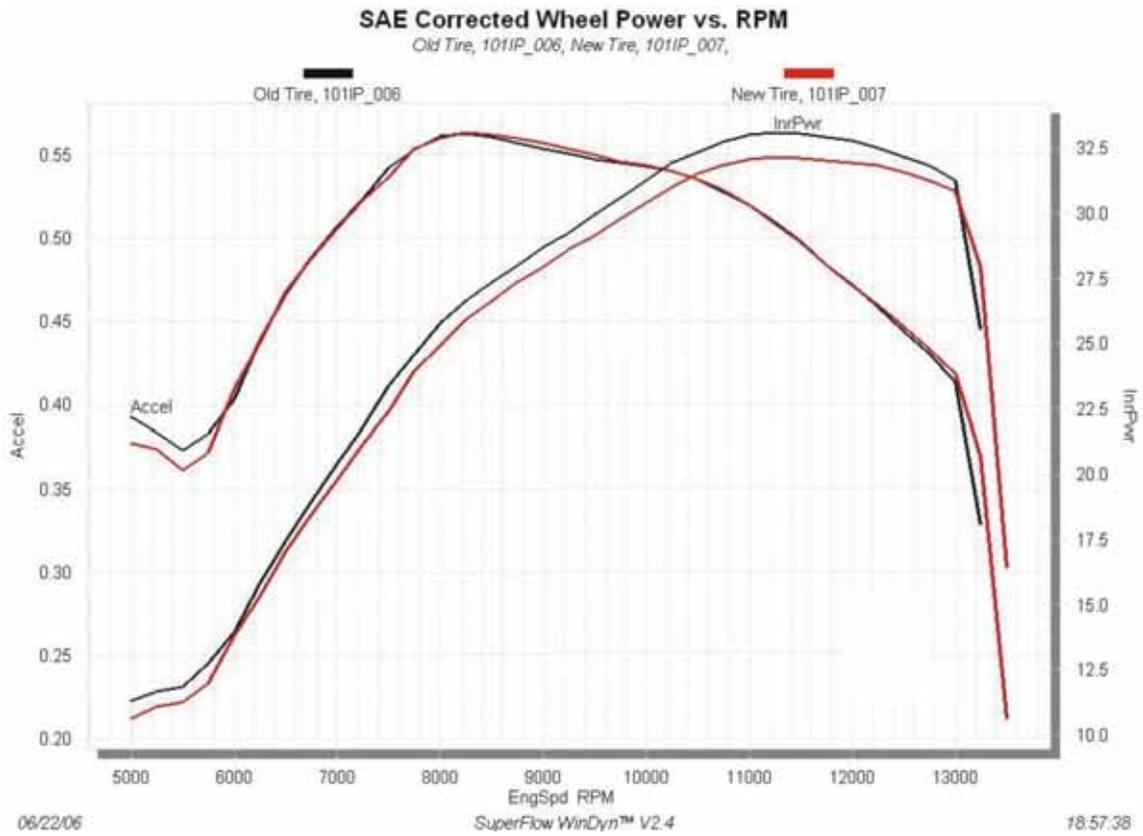
At the beginning of the test, since the new tire/wheel combo was smaller in diameter, this changed the gearing by approximately 2%, thus increasing the acceleration rate slightly and causing an increase in power at the bottom of the curve when the inertia test was performed.

A subsequent step test was performed with both tire/wheel combos, removing the effects of the inertia of the wheels. The results from those tests showed power to be exactly the same, regardless of the tire/wheel combo used.

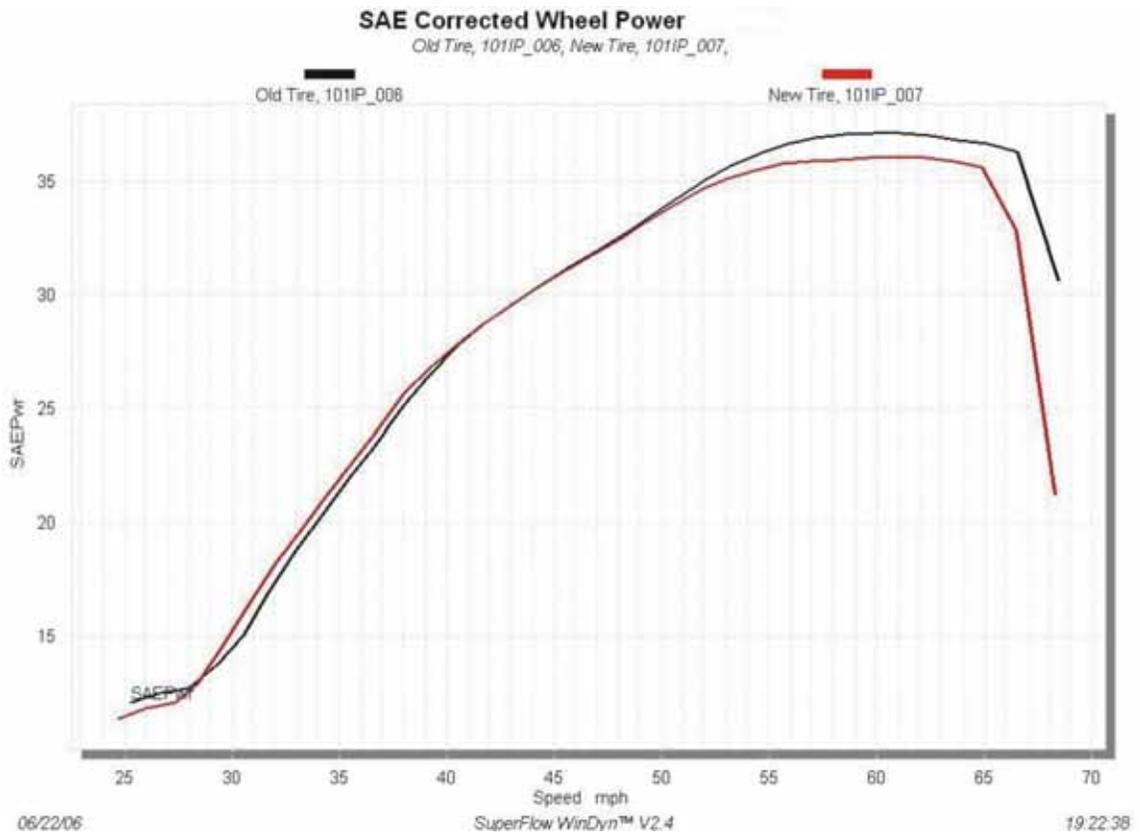


**IMPORTANT:** It is vital to pay attention to all the minor details when using a chassis dyno for comparison testing.

In the graph below, this is what the operator saw when he looked at the two power curves after changing wheels and tires. It is important to note the power curves are referenced to engine speed in this comparison.



This is how the power curves overlapped when viewed in reference to speed in mph. This creates even more confusion for the operator since he did not know the tire diameters were different or that the wheel/tire combo he just put on the bike had more inertia. His curves did not criss-cross when viewed based on engine rpm.



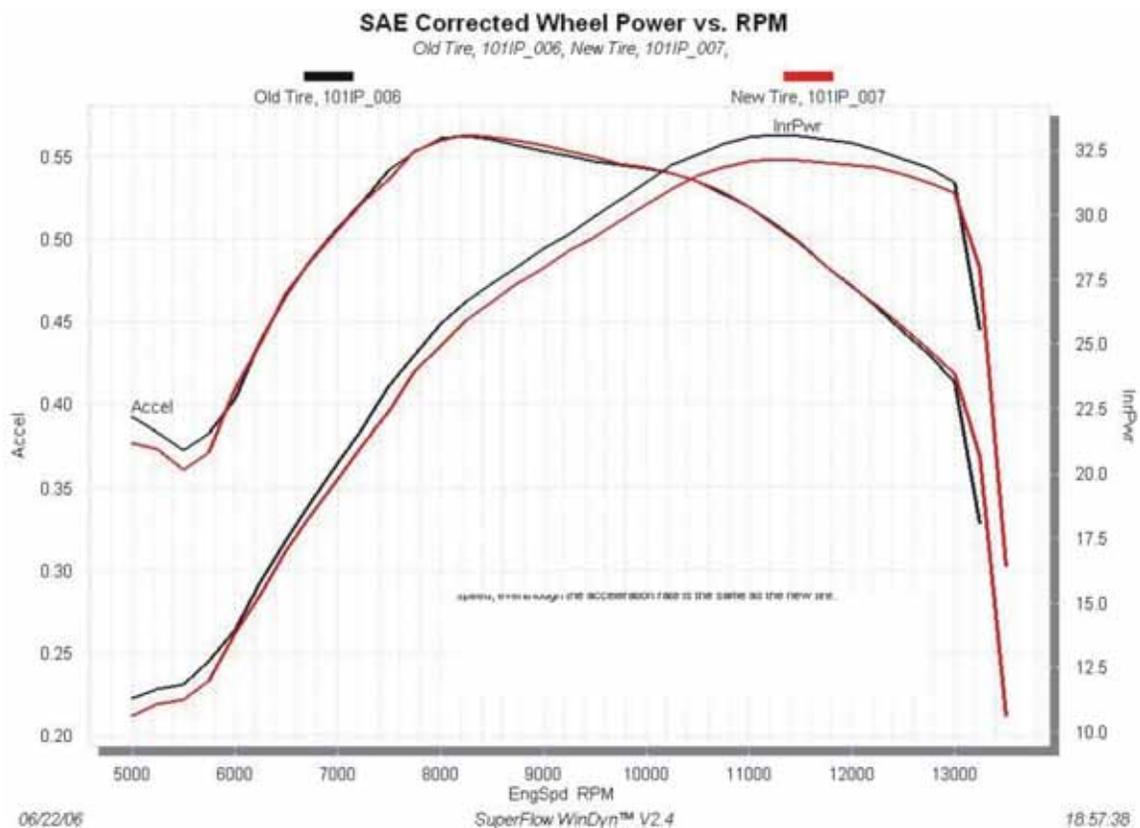
The inertia power calculation is based on two measurements taken by the dynamometer: roll speed in mph and acceleration in mph per second, or G's. In this case, the new tire had a smaller diameter by about .5 inches. This should have caused the acceleration rate to be quicker for any given engine speed (rpm).

Note that the accel rates for both tires is nearly the same; however, the new tire and wheel were also heavier (more inertia) than the old tire, which would have a subsequent effect on the rate of acceleration (slowing it down). These offset one another—in this case, resulting in two accel curves that are virtually the same. Yet the inertia power is definitely different.

The inertia power calculation also uses speed in mph in its computation:

$$\text{InrPwr} = \frac{(\text{Memry4} + 40) \times \text{Accel} \times \text{Speed}}{375}$$

Since the old tire diameter was taller, the speed would be higher for any given engine speed (rpm). Thus, the difference in the inertia power comes from the old tire's greater speed, even though the acceleration rate is the same as the new tire.



This graph clearly depicts the change in gearing that occurred from the smaller diameter new wheel/tire combo.

