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Setup Guide

Nitro Engine Tuning

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Please note: This is a guide only; there is no substitute for having your car looked at by an experienced professional.

MAXIMIZE YOUR ENGINE'S POWER POTENTIAL

So now you can get your engine started on a regular basis, but you're still struggling with the fine-tuning that will score you a win at the racetrack (or bragging rights at the parking lot). Properly tuning a nitro engine can make that difference without jeopardizing its health. It takes time to learn how to really tune your engine, however. There's a certain "feel" to how your car drives and a certain sound you'll come to know when your engine has been ideally tuned. Other cues that you feel and hear tell you what to adjust when your engine isn't running properly. When it's time to tune your engine, there's no substitute for plain old experience. Reading about engine tuning is helpful, but you need to experiment with your engine to improve your tuning skills. The good news is that the following tips will help you avoid some of the pitfalls of fine-tuning and achieve tuning proficiency more quickly.

BASE-LINE MIXTURE SETTINGS

Engine manufacturers often include base-line settings for the mixture needles, so it's wise to start with these. If this information is not provided, then you must arrive at needle settings that will get the engine started. A universal starting point is usually about 1 turn open (counterclockwise) on the low-speed needle and somewhere in the 2- to 3-turn range on the high-speed needle. This varies among engines, but it gets you started running, and then you can make the necessary corrections. After the initial startup, follow the proper break-in procedure, then worry about performance tuning!

The proper sequence for adjusting the mixture needles is hotly debated. When you start to fine-tune the engine, it's generally best to start with the high-speed needle, then set the low-speed. First, however, get your engine running, and keep it running before you worry about race tuning.

During break-in, the engine typically idles a long time, so it's best to adjust the low-speed setting first so the engine runs slightly rich (loading up every 30 seconds or so). It requires an occasional "blip" of the throttle to clear out any raw fuel that has accumulated in the engine. Once break-in is finished, then get the high-speed needle in the ballpark.

Place the car on the ground and accelerate smoothly to give the engine a chance to build some heat. With the high-speed needle in the proper range, the engine should be able to rev relatively well up to full speed once it has been running for a few minutes on the track or parking lot.

FINE-TUNING
A word of caution first: there's a fine line between the perfect tune and a blown or damaged engine. Nitro-engine fuel also contains engine lubricant, so as you get close to dialing in the mixture to where there is just enough fuel to burn and deliver maximum power, you also are close to having just enough oil to keep the engine lubricated. Anyone with experience in tuning 2-stroke engines can tell you that they run best right before they seize or blow up. Our engines are a little tougher and more capable of taking some abuse than bigger 2-strokes, but there's no sense in pushing the mixture settings so lean that you risk damage to the engine. I can't say this too often: get the engine up to full running temperature by running the car exactly as you would on the track or parking lot. The high-speed needle setting depends on the type of driving you do. I'll start with a racing setup.

HIGH-SPEED NEEDLE
Racers will tune the high-speed setting to get from point A to point B as quickly as possible. (Performance also depends on a proper low-speed needle setting, but for now, let's concentrate on the high-speed setting.) The best place to race tune your engine is on the track where you run. I prefer to set the high-speed mixture so the car can leg out the track's longest straight section in the shortest time. Estimate the time by "feel" and gut instinct, or use a stopwatch for more accuracy. The high-speed mixture should be set to maximize engine performance for that particular track configuration. A short, tight track may require a main mixture setting just a shade on the lean side to provide maximum power out of the corners. You needn't be concerned about high-rpm performance because the track is too small for the engine to ever reach peak rpm. A long, high-speed track may require a slightly rich main-needle setting. If an engine constantly revs at the upper limits of the rpm range, the fuel mixture should be richened to ensure proper lubrication across the entire rpm range. This slightly rich setting might reduce bottom-end acceleration to a degree, but longer tracks require a slightly richer mixture setting to let the engine rev to its limits without running dry of fuel and oil.

Why is it important to tune the engine to the track? A mixture needle can only provide optimum performance within a relatively narrow rpm range. Anywhere below this hypothetical rpm range, the engine runs slightly rich; anywhere above, it gets progressively leaner. Until we have fuel injection that constantly optimizes fuel mixture throughout the rpm range, there needs to be a degree of compromise with the mixture settings. So, ideally, set the mixture to provide the most power in an rpm range that is best suited to the track on which you run.

WIDE-OPEN RUNNING
Running in parking lots, particularly larger ones with a lot of breathing room, requires

unique mixture settings. It's a common mistake to establish mixture settings for maximum punch—as though the car will be run within the confines of a tight racetrack—and then to go out and run at wide-open throttle (WOT) in a huge parking lot for 5 minutes. This type of running is incredibly unhealthy for an engine to begin with, and compounding the problem with an excessively lean main-needle setting is a recipe for disaster. If you still insist on torturing your engine, the high-speed mixture setting needs to be as much as 1/4 turn richer than typical to provide optimum fuel for the upper rpm range. The engine will be a little softer when accelerating from a standstill, but it's the only way to ensure there is an adequate supply of fuel and oil when running at the upper end of the rpm range. The inherent danger is that this type of running taxes the connecting rod and other engine components to their limits, but having the proper mixture setting will at least delay the inevitable.

LOW-SPEED NEEDLE

The high-speed needle is dialed in, so now let's properly set the low-speed needle. It's important to set it last because it simply regulates the fuel that flows from the main needle at low throttle settings. Lean out the main needle, and you automatically lean the low-speed needle as well. For this reason, it's wise to finish with the low-speed setting.

Again, it's imperative for the engine to be at full operating temperature. There are many methods of testing the low-speed needle setting; one is to pinch the fuel line. When you pinch the fuel line, the engine rpm increase slightly. Keep pinching it, and the engine will eventually stall. If the engine rpm increase dramatically, it indicates that the low-speed setting may be too rich. Or, if the low-speed setting is already too lean, the engine rpm may not increase much at all, and the engine will stall rather quickly. It's a somewhat crude method and doesn't tell you what to expect from the engine on the track, but it will get you into the ballpark.

Another common way is the "see-how-long-it-will-idle" method. The low-speed needle adjustment affects how long the engine will idle. A too lean fuel mixture causes the engine to race and possibly stall, limiting the duration of a steady idle. A too rich low-speed-mixture setting causes the engine idle to steadily drop and eventually stall. The ideal setting allows the engine to hold a smooth, steady idle for 10 to 20 seconds (max), and then the engine rpm decrease steadily because the crankcase loads up with fuel. Why? There are no awards given for the longest-idling engine. If the engine is able to idle steadily for a longer time, then it may start to lean out and heat up during a race and make it difficult to drive the car and keep the engine running. The only flaw in this method is that it doesn't tell you whether you have an artificially rich mixture to compensate for an idle speed that's too high.

A common mistake is to set the idle-speed screw to keep the carburetor open too far. The low-speed needle must then be artificially rich to bring the idle down to a reasonable rpm. The symptoms are similar to a too rich low-speed-mixture setting; there's just a delay in the loss of engine rpm. How do you avoid this? This is also something that becomes easier with experience, but just continue to reduce the idle speed and lean the mixture until you know you can't go any further. Bottom line: adjust the idle-speed screw to suit the fuel-mixture setting, not the other way around.

The simplest and most foolproof method to properly set the low-speed mixture is, again, to do it on the track. Set the low-speed needle so your car gets the strongest launch after sitting still for about 10 seconds. The engine should be able to pull strongly off the line without hesitation. A noticeable hesitation might be the result of either a rich or a lean low-speed mixture; knowing the difference takes experience, but look for signs that help point you in the right direction. How an engine decelerates can tell you as much as how it accelerates. If the engine spools down and rpm drops uncharacteristically low, it indicates that the low-speed-mixture setting is too rich. Or, if the engine takes too long to reach a steady idle and seems to want to keep revving, that tells you the low-speed-mixture setting is too lean. It can also indicate a lean high-speed-mixture setting, but that setting should have been addressed by properly setting the high-speed mixture first.

It will take a little time to get it right. If you make small adjustments and are patient, you really can't do anything wrong. An adjustment you make in the wrong direction is reflected in engine performance; to correct the problem, simply go the other way.

CHANGING FUEL

Changing to a higher percentage of nitro fuel sounds like an easy method of developing more horsepower, but it isn't always that simple. Without getting into all the particulars of nitro fuel, I'll just say that there is a point where you can have too much nitro. Adding up to 10 percent more nitro than is typical produces more power, but you have to know how to adjust your engine to accommodate the extra nitro. Fuel-mixture settings need to be slightly richer when nitro content is increased. Also, you may have to increase head clearance by adding an extra head shim. The extra fuel introduced into the combustion chamber increases compression by adding non-compressible matter; this also increases cylinder pressure during the combustion process, which may cause detonation. Detonation occurs when the fuel explodes instead of burning, and that can cause internal engine damage. The extra head shim will likely prevent detonation when fuel with higher nitro content is used.

A final note about fuel: fuel with a lower oil content (for manufacturers that actually disclose the amount of oil in their fuels) should be run with a richer mixture setting. This doesn't so much relate to performance as it does to the benefit of the engine. Conversely, fuels with higher oil content have the extra lubrication that allows a leaner mixture setting with less risk of engine damage. Fuels with a lower concentration of lubricant are intended for competition use by experienced engine tuners. These fuels will make marginally more power because the lubricant that's removed is replaced with power-producing nitro and methanol. Evaluate your tuning ability honestly before you run out to buy fuel with a lower oil content.

GLOW PLUG

A glow plug's temperature range is critical to proper performance. Small-block engines generally use warm to hot glow plugs, while big-block engines use plugs in the colder range. If you choose a plug in the wrong temperature range, you could be chasing the tune of your engine till the sun goes down. Changes of the relative temperature of the glow plug can be beneficial, however.

A combination of compression, heat and a catalytic reaction between the platinum in the glow-plug coil and the methanol in the fuel creates combustion in a nitro engine. Altering the heat range of your glow plug can alter the timing of the combustion process. Nitro engines don't have an ignition system that can be used to advance or retard combustion timing, but a hotter plug that causes ignition a little earlier in the combustion process can have the same effect. "Advancing" the ignition timing can increase overall power output, especially at higher rpm. There are limits, however, and installing too hot a plug causes pre-ignition (detonation) and risks damaging your engine.

It's a challenge to figure out a glow plug's temperature range. Manufacturers don't use a consistent and universal standard to rate the temperature ranges of their glow plugs. You will probably know the temperature of a plug relative to others within a given product line, but currently, no rating system allows comparisons among manufacturers. Here again, plain old experience with a variety of glow plugs will help you to know which are best for the effect you want.

"Reading" the glow plug is a tuning technique advanced by Ron Paris. It suggests that looking at the glow plug tells you something about how your engine is running. The element in a glow plug will turn gray in an engine that is close to the optimum fuel mixture. This method requires a new glow plug, as the element will eventually turn gray regardless of the needle settings; the length of time it takes to turn gray is the issue. Plugs that turn gray in just a tank or two of fuel (running at race pace, not diddling around) indicate a fuel mixture close to ideal—but also close to trouble. If the plug stays wet and shiny for a few tanks of fuel, you're in the safe zone; a little rich but safe. When the plug wire gets distorted or broken, however, you're in real trouble. It's a sure sign that the mixture is way too lean, or that there is too much compression and the engine is detonating.

HEAD SHIMS

Engines are essentially air pumps. The engine takes air in, mixes it with fuel, and then the mixture is compressed and ignited. The additional pressure created by the burning fuel increases by a factor directly related to the amount of compression: increasing compression increases power output. But there are limits to the compression an engine tolerates. Too much causes the fuel mixture to combust too quickly, and that returns us to the same detonation scenario of an excessively hot glow plug.

The amount of compression is determined by the number and thickness of the shims (gaskets) between the cylinder head and the top of the piston sleeve. Well, it's determined by many other factors, but the only one easily changed is the head clearance via head shims. More shims = less compression; less shims = more compression. Removing or replacing shims with thinner ones increases compression. Some engines have only one shim, so it isn't advisable to run without a shim at all. Moderation is the key. Go slowly, and make small, not drastic, changes that will minimize the risk of damage to your engine. First and foremost, be sure the piston won't hit the cylinder head if you remove a shim (or shims).

You can also change compression with glow plugs. Some manufacturers make a longer glow plug that protrudes slightly into the combustion chamber, effectively reducing the area in which the fuel mixture is compressed. This area is already small, and the little extra space occupied by a longer glow plug will raise compression. This is not the most desirable method, but it can be used on engines that have only one thin head shim. It's unlikely that the longer plug will even come into contact with the piston, but just to be safe, check the head clearance before you install a long plug.

WEATHER CONDITIONS

It's a simple fact: for optimum performance, you must retune your nitro engine every time you run it. Anyone who assumes that the needles can be left alone once they have been set is sadly mistaken. An overnight change in weather conditions may prevent an engine from running or may put it at risk of some damage if adjustments aren't made to the fuel-mixture settings. Ignoring an engine's tuning needs compromises its ability to make horsepower. In response to certain changes in weather, equipment and other variables, nitro engines must be regularly retuned.

Temperature. Hot weather requires a leaner mixture setting; cold weather requires a richer setting. Most people assume the opposite because they treat the mixture needle like a thermostat. It is wrong to assume that colder weather requires a leaner setting to keep heat in the engine and vice versa. Cold air is denser than hot air. The denser, colder air packs more oxygen into the engine, so going from hot weather to cold needs a commensurate increase of fuel to balance ratio of fuel-burning oxygen and the fuel itself. The opposite is true in hotter weather. Going from cold to hot weather requires a leaner mixture setting.

Humidity. Humidity is the amount of moisture (water vapor) in the air. Moisture in the air takes up volume that would otherwise be occupied by fuel-burning oxygen. Less oxygen means less fuel is required to maintain a proper ratio of air and fuel. High humidity requires a leaner mixture setting than dry conditions.

Barometric pressure. A barometer measures the atmospheric pressure (generally listed in the local newspaper or on the local weather forecast on TV). Higher barometric pressure readings mean more air is getting into the engine, requiring a richer mixture setting to balance the air/fuel ratio.

Altitude. Altitude is an important factor that most of us ignore, yet it affects the engine's performance possibly more than any other element. The general formula for power loss with increases in altitude is 3 percent for every 1,000 feet above sea level. If you race in Colorado at 5,000 feet instead of in California at sea level, you can expect to lose about 15 percent of the engine's potential power output, if the engine is tuned properly.

Air is thinner at higher altitudes, which means there's less fuel-burning oxygen than at sea level. You might sense a common theme here: less air (oxygen) means less fuel to maintain the proper air/fuel ratio. So, running at higher altitudes requires a leaner mixture setting than running at sea level.

TUNING

This chart indicates the direction in which you should adjust the fuel mixture when faced with changing weather and other conditions. It assumes the engine is currently well tuned. You could face any combination of conditions listed in the chart; knowing which way to go with the mixture adjustments is half the battle.

Higher air temperature	Lean	↻
Lower air temperature	Rich	↺
Higher humidity	Lean	↻
Lower humidity	Rich	↺
Higher barometric pressure	Rich	↺
Lower barometric pressure	Lean	↻
Higher altitude	Lean	↻
Lower altitude	Rich	↺
Higher nitro content	Rich	↺
Lower nitro content	Lean	↻
Higher oil content	Lean	↻
Lower oil content	Rich	↺
Hotter glow plug	Rich	↺
Colder glow plug	Lean	↻

TUNED PIPE AND HEADER

Anyone who has been around 2-strokes knows that the exhaust system plays a major role in engine performance. Pipes and how they affect performance is a complete article in itself. I don't want to get into the science of tuned pipes here, I'll simply suggest that volume (assuming the pipe doesn't stray too far from convention) determines where the pipe will go to make the best power. Smaller pipes with lower overall volume make the best top-end power, while the fatter, longer pipes with greater volume provide the best bottom-end punch. Selecting the proper tuned pipe can have a very noticeable impact on your application.

Headers can be modified by almost any enthusiast. The length of the header is important to squeezing more power out of your engine. Longer headers deliver better bottom-end power, while shorter headers make better top end. Shorten a header by cutting it with a hacksaw or a Dremel tool. Cut it in 1/8-inch increments, and measure the performance to determine whether any improvement has occurred. Continue cutting until performance levels off. If you need to add back on to the length of the header because you've cut too much and performance is suffering, simply increase the gap between the header and pipe, but don't expose more than 1/4 inch of coupler. If the header is too short by greater than 1/4 inch, just get a new one.

CLUTCH

I've spent lots of time trying to chase away a nasty bog in the engine as it came off the line or out of a corner, only to find later that the problem was the clutch. Some clutches are built properly at the factory, but in my experience, most engage too early, which hobbles the engine coming out of every corner. Tuning the clutch to engage at the proper rpm puts more power to the ground than most could imagine.

TEMPERATURE GAUGE

You'll notice that I have not once mentioned a temperature gauge. The worst thing you can do is to tune an engine to run at a specific temperature. Engine temperature is affected by a number of factors, only one of which is fuel mixture. Weather and many other factors play a role in engine temperature, so tuning to run at the same temperature every time shortchanges the engine's potential to make power. Yes, most engines run in the 200- to 300-degree range, so checking that the engine stays within this range is valuable to a certain extent. As a result of different weather conditions and other variables, however, the same engine—when tuned for peak power output—can vary as much as 50 degrees. A temp gauge is a reference tool that you should use only to build a data bank of tuning information. A temp gauge should not be used as a tuning tool. Don't tune an engine to run at 230 degrees all the time. Prevailing conditions may require a mixture setting that causes the engine to make maximum power while running at 270 degrees. You'll never know that if you always target the same temperature.

CONCLUSION

Engine tuning is not a black art; it just takes time to learn the particulars so you can maximize your power plant's performance. Take the time to read and learn, and you will avoid the mistakes most of us made in learning the ropes. I thought I had it licked 10 years ago, but I'm still learning. We never really stop learning; sometimes, we just get too smart for our own good. Experiment a little with some of the tips, and you'll find there's more power to be made with less effort than you thought. Some of the modifications involve a bit of risk; just take it slowly, and use your "noodle." It's hard to make a mistake you can't correct.