GAS ENGINES OPERATING MANUAL – MARCH 2011

Disclaimer
The following information is not specific to any one engine and is intended as a general guideline. Use it at your own risk. No warranty is made as to its accuracy. I strongly suggest that you follow the manufacturers instructions that came with your engine.

Gas Engine Tuning
Do not use the largest recommended prop. Use one that allows the engine to operate within its maximum power band. Set the timing first, then low needle and finally high needle. Fly the plane and check the engine response in the air. Adjust as necessary. Remember to adjust the high needle after adjusting the low needle as the low needle setting affects the gas supply throughout the entire throttle range.

Needle settings
Gas Engine carbs have 2 needles – a high speed needle and a low speed needle. These work together and when one needle is adjusted it usually requires some adjustment to the other needle too. The LOW speed needle is always closest to the engine. The HIGH speed needle is furthest from the engine.

When tuning a gas engine I usually start with both needles at approx 1 ¾ turns out. Start the engine and get it running and let it warm up. Don't try and set the needles on a cold engine. Once the engine is warm, start with the low end needle first. Lean this needle as much as you can until when you open the throttle it wants to die. At this point you have gone too far. Richen the needle and try again. What you want is to lean the low end as far as you can, but the engine still responds instantly to throttle inputs. If it hesitates or cuts out then the low-end needle is too lean. If it burbles and sputters before coming up to speed the low-end needle is too rich. When you have that right the low end is set. Now open the throttle to WOT. If the engine runs rough or you are not getting good rpm start by leaning the high end needle. Lean this needle until you get max rpm. If you open the throttle and at WOT, you can hear the rpm sagging, you are too lean, richen the needle and try again until the engine runs at max rpm without sagging. At this point the high end is set.

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Now check the idle and throttle transition from Low to high. It should all be set. Sometimes you will have to repeat these steps until you get the best settings. (remember when tuning these needles on some carbs all it takes is $1/16^{th}$ of a turn to get it right, don't adjust in ¼ turn increments) at full throttle the fuel enters the carb through both needles, hence the reason they must work / be set together for best results.

Gas engines are NOT the same as glow engines. With glow engines you set for max rpm and then always richen the needle slightly. Gas Engine needles must be set and left as is. A rich needle setting does not help an engine run in faster, better or offer better lubrication. If you want better Lubrication change your fuel mix BUT do NOT run it rich. The engine will run properly when it is receiving the correct fuel mixture (amount of air and fuel) from the carburetor.

The amount of air it receives is controlled by the throttle (butterfly) and how far it is open. The amount of fuel that it receives depends on the settings of the Low-and High-end needles.

The engine draws fuel from the low-end (idle) needle at all times. As the engine RPMs increase to 2,000 – 3,500 (called the midrange) it also draws fuel from the high-end needle. As the RPMs increase further, it draws even more fuel from the high-end needle. The trick is to adjust the needles so that the engine gets the right amount of fuel for all throttle settings (butterfly openings).

The term **"Lean"** means that there is less fuel or more air being delivered to the engine from the carburetor for a given butterfly opening (throttle setting). The engine will run faster, smoother, and hotter as the mixture is "leaned", provided that it is not leaned too much causing the engine to over heat and "sag".

The term **"Rich"** means that there is more fuel being delivered to the engine by the carburetor for a given throttle setting. The engine will typically run slower, cooler, and less smoothly and will probably foul the sparkplugs if it is too rich.

Generally, the Low-end needle is set as lean as possible while still retaining the ability to instantly transition from idle to the midrange. If the idle is set too lean, the engine will hesitate and probably die if the throttle is advanced quickly from idle. If the idle is set too rich, it will spit, sputter, and burble when the throttle is moved quickly from low to high because it is trying to burn excess fuel.

The High-end needle is set correctly when the engine turns maximum RPM without overheating. If set too lean over-heating will occur, causing the engine to "sag" or otherwise slow-down and will cause damage to the engine. This can show up while flying when the aircraft is climbing vertically or pulling through loops. If set too rich, the engine will not run smoothly and will not develop full power.

The carburetors have two needles that are used to adjust Low-end (idle and midrange) and High-end (full throttle) fuel mixtures. The LOW speed needle is always closest to the engine. The HIGH speed needle is furthest from the engine.

When a needle is screwed "in" (turned clockwise) it "leans" the mixture by restricting fuel flow. When a needle is screwed "out" (turned counter-clockwise or CCW) it richens the mixture by allowing more fuel to flow through the carburetor and into the engine.

If for any reason the needle settings are completely lost, or you are unsure of your settings, start by screwing the needles all of the way in, but be careful and do not to over-tighten them or their seats may be damaged. Close them just enough to be snug. Now open them each 1 3/4 turns for initial settings.

Reading your Spark Plug

Gas engine owners should be prepared to remove your plug and learn how to read a plug. Reading a plug can tell you a lot about how your engine is set up and its condition. There are many informative pages on the net on this.

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Reading plugs to help tune the engine:

The ideal plug will look something like this: The porcelain is chocolate colour (leaded fuel) or very light brown, almost white (unleaded fuel), the tips of the electrodes (center electrode and side electrode) are grey and the rest of the side electrode is straw colour. There will be some deposits on the plug, but only dry and low gloss, no shiny and no wet deposits. And of course you can see the narrow bluish ring around the electrode, approximately 1mm from the tip.

If the mixture is too rich the plug will be sooty brown/black. If the tips of the electrodes are grey, then the plug is still firing, so it's a mixture issue, but if the electrode tips are also sooty brown/black, the plug doesn't fire, and that has to be fixed before the plug can be read, the sooty brown/black stuff will maybe disappear when the plugs starts firing again. If the mixture is too lean and you use leaded gas the porcelain will be all white and the center electrode tip can be white as well. If you use unleaded gas, things are more difficult because an engine in perfect tune will almost not colour the porcelain. Look for white center electrode, signs of overheating like bubbles and burnt electrodes to help find a too lean condition.

We recommend going slightly on the rich side. And since it's difficult to see the difference between OK and lean, that's another reason to go a too rich, for peace of mind. So our recommendation is to be a little too rich, have plugs that are somewhat sooty brown, at least not white. Then you know you're alright and have a margin of error on your side.

Good Needle settings 	Grayish-tan to white in color indicates the plug is operating at the proper heat range as well as correct jetting and the cylinder is running healthy. Note that on modern unleaded fuel burning engines that it may be difficult to see the coloration that is so obvious on the plug above. Plug should be clean and free from deposits.
Engine Too Lean - Overheating problems 	On this symptom you will notice a chalky appearance, white insulator, rapid electrode wear as well as an absence of deposits. The actual shell may also be discolored whitish or even a blue / bronze colour.
Engine far too Rich 	Black / sooty and wet deposits. The engine is running rich and the needle setting are incorrect. Clean plug, reinstall and start with re-setting both needles.
Engine Slightly Rich 	This is very common visual condition. Soft, black, sooty, dry-looking carbon. This indicates a rich mixture, weak ignition or wrong heat range plug (too cold).

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SPARK PLUG GAP:
The normal range for the spark plug gap is .020" - .025". Do not exceed these limits. We recommend starting with a gap of .022". If the engine runs rough in the midrange after the carburetor and ignition have been properly adjusted, then try increasing the gap slightly. If the engine misses at full throttle, try decreasing the gap slightly.

Starting a brand new Gas Engine
New gas engines are often difficult to start as the rings do not seat within the cylinder walls, the engine and carb are 'dry', and the resulting pressures required to drive the carb pump diaphragm are not great. There is an easy way to solve this.

Fit the engine to a test stand mounted with the cylinder facing upwards and connect up the fuel supply to the carb. Now remove the spark plug from the engine and use some of your 2 stroke oil (the same you have used for your fuel mix is fine) and drop 5-10ml through the plug hole into the cylinder. Turn the engine over by hand to distribute this oil.

Now with the plug still removed use a starter motor to turn over the engine. You should see the fuel mix drawn down the inlet line and into the carb. Don't stop when you see it at the carb. Keep turning it over to make sure you fill the carb with fuel and it is pumping through into the engine. Watch the open plug hole until you can see the gas mix spraying out. At this point the carb and engine should be well primed and wet with fuel mix. Now you can replace the spark plug, connect up your ignition and fire her up.

In the case of a twin cylinder with a carb on the bottom of the crankcase, mount the engine with the carb and exhausts facing upwards, and follow the same procedure as above. In the case of engines with carbs on the bottom of the crankcase, until the engine has done 15-30 minutes of run time it may be difficult to get the engine to 'suck' the fuel upwards and into the carb. I have often heard guys saying "there is plenty fuel because it is dripping from the carb". It doesn't matter how much fuel you have at the carb, it's what you have in the engine that counts.

Starting a Gas Engine

To start your engine make sure everything is connected, close the choke and put the ignition **ON.** Flip the prop until the engine fires but stops, now open the choke, ignition still on and flip again. 2-3 good flips and she should run.

If after a few flips you are not getting any 'popping' and the engine wanting to start, again close the choke – leave the ignition and flip again to further prime the engine.

If you choke the engine and leave the ignition off you will not know when the feul / air mix is just right inside the engine, and I have seen many guys battling to start engines because they flood them. A flooded plug WILL NOT FIRE. If you do flood the engine, remove the plug, turn over the engine and be sure to blow the excess fuel from the plug itself. Replace plug and start again.

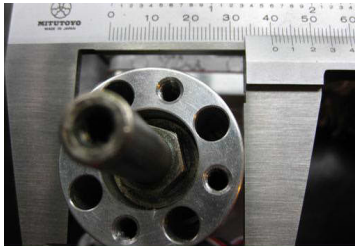
Fuel Mix

We recommend standard unleaded fuel with a good quality synthetic 2 stroke oil. We have had very good results with Putoline MX5 racing oil and Stihl Ultra HP. For run in we recommend 30:1 mix for the first 5 litres. If you wish you can go to 50:1 thereafter. We run 30:1 in all engines whether run in or not – More OIL is better and there is no performance gain to be had with 50:1 vs. 30:1.

Timing Your Engine the Easy Way

There have been NUMEROUS posts on various forums about engine timing...

A. First off, a degree one way or the other will make NO difference in performance.. NONE… PERIOD.
B. Second, you DO NOT NEED a degree wheel or dial indicator to time an engine.
C. Third, engines using a HALL SENSOR are easy to time.
D. Fourth, there is NO advantage to setting the timing to more than 30 degrees TDC...NONE, All you do is make the engine run hotter.



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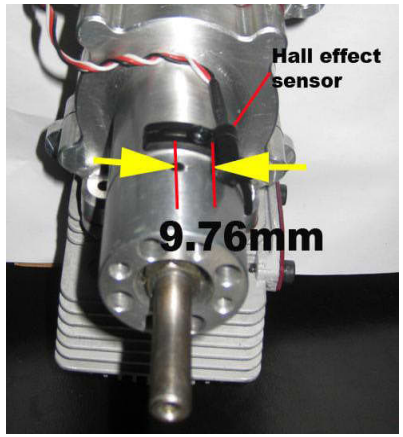
Please be aware that different engine brands may have the sensor magnet in a different location than what is shown here. Don't Panic. The math is the same… as is where you position the Hall Effect Sensor.

Here's the way to do set your timing…….

ALL it takes is a Vernier caliper and a calculator…

1. Measure the diameter of the hub...
Multiply by .244 for 28 degrees TDC...This number comes from the formula Diameter x Pi, 3.14, divided by 360 for 1 degree, x 28...Save this number.
Using the MT 35cc hub - The diameter of the hub = 40mm
40mm x .244 = 9.76mm
The distance from the prop hub magnet to the hall sensor will need to be 9.76mm to achieve the 28 degrees timing.
(for practical purposes you can just use 9.8mm as the distance)



2. You need to rotate the prop hub until you reach Piston Top Dead Center (TDC).

3. On the Mt 35cc engine the magnet that activates the hall sensor will be located near the bottom side of the hub. The pic shows what we mean and the location. You will notice that the magnet is located dead center. The magnet and the piston in TDC position are perfectly aligned in the vertical plane… So far so good… you are almost done… Now it gets easy!

4. In step one we did the math to determine where 28 degrees would be on the hub. The answer is 9.76mm….. That is the distance from the center of the magnet to the closest EDGE of the HALL sensor…. Tighten the screws on the hall sensor. Use a dab of loctite too… You are done… That's all there is to it, NO BIG DEAL....

Carb assembley – please note the following when stripping your carb for cleaning or to replace the carb membranes....

On the fuel pump side of the carb (one large screw in center), put the diaphragm on the carb first, then the gasket, then the cover. On the metering side of the carb (stamped steel cover, 4 small screws), put the gasket on the carb first, then the diaphragm, then the cover.

Definitions:

Running rough:	Popping, spitting, spluttering, burbling.
Goosing:	Opening the throttle from idle to full very quickly.
Lean:	The term **lean** means that there is less fuel being delivered to the engine from the carburetor for a given throttle setting. The engine will run faster, smoother and hotter as the mixture is leaned, provided that it is not leaned too much.
Rich:	The term **rich** means that there is more fuel being delivered to the engine from the carburetor for a given throttle setting. The engine will run slower, cooler and less smoothly and will probably foul the spark plugs if it is too rich.

Timing:	
Process:	Never take is that it is preset by the factory. Exact settings depend on the engine type and model but are usually around 2-5 deg BTDC at idle and 28 deg BTDC at full throttle. Timing should be set as retarded as possible without max RPM loss. For those without fancy testing equipment, run the engine until hot then measure max RPM. Retard the timing a little and re-measure. If max RPM drops, advance timing a little.

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Symptoms:	Too Advanced: Loss of Max RPM Kick back and possibly throw prop when starting Pings Hard to start Engine will miss Too Retarded: May start backwards Slow to accelerate Low power Runs hot
Low Needle:	
Process:	Keep in mind the **low needle affects the high one** but not the other way round. The low needle should be set as lean as possible without displaying any of the bad symptoms mentioned below. First get it to run smoothly at idle, then try goosing it to about 1/3 throttle. Adjust until the transition is smooth.
Symptoms:	Too Rich: Runs rough and shakes badly Burbles in midrange and smoothes out at full throttle Engine will transition slowly May die after idling for a long period Too Lean: Hard to start Won't decelerate (hangs at higher revs for a while) Dies when 'goosed' to full throttle
Warnings:	Setting too lean may cause a dead stick when opening throttle after a long downline.

High Needle:	
Process:	Keep in mind the **low needle affects the high one** but not the other way round. Bring the throttle up to high and back the high needle out till it runs rough / rich. If you can not get the needle to produce an over rich condition then you have insufficient fuel flow (example: tubing may be too thin). Fix it and then restart the tuning process. The high needle should be set to gain maximum RPM without overheating. When running in it should be set VERY slightly rich. Measure the RPM and slowly close the needle as long as RPMs continue to climb. If RPMs flatten out or fall then back off about **1/16 of a turn**.
Symptoms:	Too Rich: Full throttle blubbers Will not develop full power Too Lean: Runs hot Sags on uplines May die in flight Will not run at full throttle
Warnings :	Setting too rich may cause the engine to generate carbon deposits and foul the spark plugs.

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Conclusion / Confusion
Mixed symptoms

Runs hot:	May be caused by high needle being too lean and/or by timing being too retarded, or simply poor cooling.
Hard to Start:	Could be timing, needles or any of a host of other causes. Check low needle too lean and/or timing too advanced.
Runs rich:	May be caused by low ignition battery; make sure it is fully charged when setting up engine.
And finally:	Bad or stale fuel and/or a bad or leaky plug can cause a host of problems that would be difficult to diagnose.

Cannisters:
These have no tuning and therefore have good transition from idle through mid range to high throttle. I prefer canisters over tuned pipes for throttle response, but the tuned pipes add HP, while the canisters do not. There are many different types of canisters though. Cooling is critical on all canister mufflers. Good airflow is required to keep the canisters cool. If they are not kept below 130 F, they will anneal and fail. Failure is the stinger breaking off or the can rupturing. Proper mounting is critical on all canister mufflers. Holding the mufflers in place, yet allowing some movement i.e. soft mounting is critical. Holding the mufflers in place and not blocking airflow is a delicate balance. More on this subject later....

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