And last but not least, although somewhat obvious, it bears remembering that the content presented here was taken from serious and proven studies. It also comes from the author's experience, but always based on the concepts of physics and supported by logic, common sense, and personal perception.

- Bibliography:

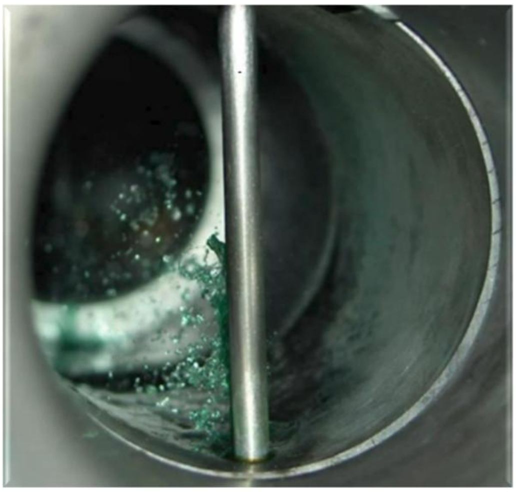
- Design and simulation of two stroke engines – Gordon P. Blair
- Two Stroke Tuners Handbook - Gordon Jennings
- Two-Stroke Performance Tuning – A. Graham Bell
- Le gonflage des cyclomoteurs - Didier THOMAS
- Dragonfly – Michael Forrest
- Study of the influence of exhaust manifold geometry – Ariel Kaplan
- Between others

Chapter 2 – Carburetor

2.1 Introduction to the Carburetor

This is a very debatable topic, but we will approach it with case studies and bibliographical references that support our thinking.

According to Michael Forrest, the carburetor must be sized so that the air/fuel mixture is formed by both small and large droplets. The small droplets serve to generate power, while the large droplets cool hot parts and carry oil to moving parts such as bearings and cages.



Therefore, a small carburetor has a higher flow velocity and can only generate small droplets, which favors power but does not provide engine cooling.

A large carburetor, on the other hand, delivers, for the most part, very large droplets. The engine will run cooler, but you should notice a loss of power.

Therefore, according to him, the ideal carburetor must provide a compromise between power and lubrication and cooling capacity as shown in the photo alongside.

It should be noted that this condition mentioned is only at WOT (100% acceleration).

This is why small carburetors generate better fuel economy, as the vast majority of droplets are small, favoring power. And of course, they're used in low-performance engines where one of the design prerequisites is precisely range.

So far we have talked about carburetors that are ideal for maximum performance and in engines that require this condition.

Graham Bell provided us with a table as a reference point. It outlines three operating conditions: enduro, motorcross, and street racing. This is a starting point for ultra-high-performance engines.

We noticed that even a small-displacement engine requires a large carburetor. We consider this engine to have a very large intake capacity.

And that's what we need to think about every time we're selecting the best carburetor: considering how much air the engine can take in to optimize the mixture optimally.

TABLE 5.3 Recommended Mikuni carburettor sizes

	Carburettor size (mm)		
Cylinder size (cc)	*Enduro*	*Motocross*	*Road race*
50–62			27–29
80		27–29	29–32
100		30–32	32–34
125	30–32	33–36	35–38
175	33–35		35–38
250	36	37–40	40–42
350–500	36–38	38–42	40–44

I created a more complete table for you to use.

CARBURETOR SIZE INDICATION ACCORDING TO DISPLACEMENT/APPLICATION							
Displacement (CC)	**APPLICATION TYPES**						
1 carb per cylinder	*Original*	*Street (day to day)*	*Road)*	*Enduro / Trail*	*kart/motorcycle (circuit)*	*Motocross / Velocross*	*Runway 201/402m*
50	12	13	14	x	19	19	24
60/70	14	15	16	x	24	24	26
80	19	21	22	x	27	27	28
100	21	22	24	x	30	30	32
125	23	24	26	30	33	33	34
150	24	26	28	32	35	35	36
175	25	27	30	33	36	36	37
200	26	28	32	35	x	37	38
250	28	30	34	36	x	38	40
300	30	32	36	37	x	39	42
Note: The greater the power generated, the greater the need to increase the venturi diameter.							

2.2 Function of the Carburetor in a 2-Stroke Engine

The carburetor's basic function is to prepare the air-fuel mixture for the engine. It works by utilizing the depression created in the crankcase during piston movement. When the piston rises, it generates a vacuum that sucks air through the carburetor. This air, as it passes through the diffuser, draws fuel from the main jet, creating the mixture that powers the engine.

In a two-stroke engine, the carburetor is even more important because the entire cylinder filling depends on the flow of gases. Unlike a four-stroke engine , there are no intake valves to control the air flow. The piston controls the opening and closing of the intake port, and the carburetor must be in sync with this cycle.

If the carburetor is too small, it limits the amount of fuel entering the engine. This results in reduced power and difficulty reaching higher RPMs. A carburetor that's too large reduces flow velocity, impairs fuel atomization, and causes misfires at low RPMs.

2.3 Relationship between Carburetor Diameter and Performance

The carburetor diameter is directly related to the engine's rotation range and behavior.

- **Smaller carburetor** → higher air velocity passing through the diffuser. This favors fuel atomization and improves response at low and medium revs. It's the ideal choice for engines that need torque early on, such as in urban use or on technical trails.

- **Larger carburetor** → lower air velocity at low rpm, but greater mixture volume at high rpm. This increases performance at high rpm, but can compromise drivability at low rpm. It is best suited for race-tuned engines that operate at high rpm.

The key is finding the right balance between the carburetor and the engine's power output. A larger carburetor won't always provide more usable power. In many cases, a moderate carburetor provides better performance across the entire RPM range.

2.4 Common Mistakes When Choosing a Carburetor

A common mistake is to believe that simply installing the largest carburetor possible will give you more power. This approach usually backfires. The engine becomes "dead" at low revs, difficult to tune , and often even weaker under real-world conditions.

Another mistake is to use only the carburetor that originally came with the engine as a reference. Manufacturers choose carburetors to balance fuel consumption, emissions, and production costs, not necessarily to maximize performance. Therefore, tuned engines often benefit from a different carburetor, but always respecting the sizing logic.

It's also common to overlook the rest of the system. A large carburetor without a properly dimensioned exhaust, reworked ports, or a suitable cylinder head will hardly yield results. As we saw in the previous chapter, real gains come when all components are in tune.

2.5 Practical examples of sizing

To better understand, let's look at some practical examples. A stock 125cc engine, with factory exhaust and ports, generally works well with carburetors between **24 and 28mm.** This is the ideal size for good low-end response and mid- and high-end performance, without compromising drivability.

If this same engine receives light preparation — sports exhaust and reworked cylinder head — it can benefit from a larger carburetor, between **28 and 30 mm.**

In competition engines, with enlarged ports, dimensioned exhaust and high working rotations, it is common to use carburetors of **32 to 38 mm,** depending on the displacement and level of preparation.

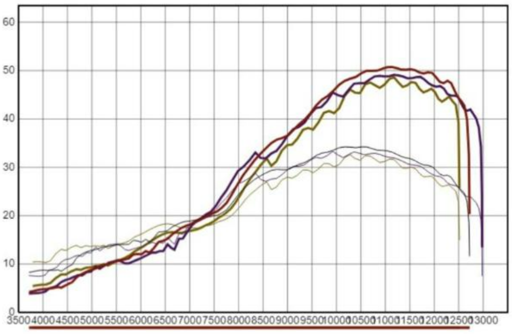
On small engines, such as 50cc , a carburetor between **16 and 19mm** is usually ideal for general use. Putting a 24mm carburetor on such a small engine will likely do more harm than good unless it's been heavily tuned for racing purposes.

These examples show that there's no "magic carburetor" that fits all needs. It's always necessary to evaluate the engine, its setup, and its intended use.

2.6 Final considerations

In my experience, when you exceed the ideal carburetor size, the engine starts to deny acceleration at low RPM and you suddenly accelerate at 100%. The engine doesn't have enough airflow to activate the carburetor's venturi effect, which prevents fuel from rising through the diffuser, resulting in too much air and too little fuel, causing the engine to stall due to lack of power. Similarly, we can, in practice, increase the carburetor size, always starting from the original design size of that engine and checking the power increase, until we notice no further gain. This means the carburetor size is sufficient for the engine's aspiration. In this case, back off the carburetor size by 1 or 2 millimeters.

In practice, I'll show you below the power difference by swapping a 38mm carburetor for a 42mm carburetor on a Yamaha DT180 racing engine. The graph shows a lower power output of 48.59 hp with the 38mm carburetor. Above it, the graph shows 49.1 hp with the 42mm carburetor. Since I verified that the carburetion was correct with the exhaust probe, which is a copper tube inserted into the exhaust, and I had already noticed that removing it would produce more power, I did just that. By removing the exhaust probe, the engine delivered 50.7 hp, while I estimate a minimum of 56 hp, a historic milestone for this type of engine, which was initially rated at 16 hp according to the manufacturer's specifications. Throughout this study, we will provide more details, limiting ourselves here to the effect of the carburetor change.



Brown line (48.59hp), blue line (49.59hp), red line (50.7hp)

2.7 Types of Carburetors

Two-stroke engines basically have two types of carburetors: guillotine carburetors and pump-action carburetors. Guillotine carburetors are the most common and easiest to install. However, adjusting them requires more knowledge and attention. These carburetors typically have two jets—one for low and one for high—in addition to the air screw and the needle adjustment, which operates in the mid-range. Pump-action carburetors, such as the Tillotson and Walbro models, require more complex installation because they require a vacuum port connected to the crankcase. However, adjustment is simpler and more practical, made externally with two main adjustments: one for high (H) and one for low (L), both accessible with the engine running.

2.8 Operation of guillotine carburetors

Guillotine carburetors do not have a fuel pump to assist in filling the tank. Fueling occurs solely by gravity. This means that when using more fuel-efficient fuels, such as ethanol, the entire fuel path must be reworked—from the inlet nipple to the needle. These carburetors are originally designed for gasoline. Some replica TM carburetors have larger fuel inlets and work well with ethanol, available in sizes ranging from 24 to 38 mm. In the case of methanol, there is no guarantee that the fuel supply will be sufficient. In short races, such as 201-meter sprints on the track, the tank volume may be sufficient to feed the engine, but in continuous use, such as on the street, it tends to run out of fuel. In these cases, the use of an auxiliary system is recommended, such as a bypass with extra fuel supply or a carburetor-specific fuel pump, which operates at around 0.5 bar of pressure.

2.9 Operation of carburetors with pump

Pump-type carburetors work similarly, regardless of manufacturer. They have two main settings: low (L) and high (H). Adjustment always begins with low, which is responsible for idling and the mixture transition from low to high, preventing misfires. It's recommended to start the low setting with two turns open. Once the idle setting is adjusted, move on to the high setting, usually starting with two and a half turns. This process provides a suitable baseline for the finer adjustments that follow.

2.10 Adjusting the guillotine carburetors

Guillotine carburetors have four adjustments. High-rev is adjusted by the main jet. Medium-rev is adjusted by the needle and the diffuser opening, which is the spool where the needle passes. Low-rev is adjusted by the low-rev jet in conjunction with the choke screw.

It's important to understand that one stage affects the other. The low will affect the average, which, in turn, will also affect the high.

Therefore, from the bottom up, there will always be interference, but from the top down, there won't be. In other words, the high doesn't interfere with the average, and the average doesn't interfere with the low.

High and low pressure adjustments are made by jets, but medium pressure is adjusted by needle height. If the needle is already at its highest position and the symptom is low pressure, we need to file the needle to remove material and increase the clearance between it and the diffuser. If the needle is at its lowest setting and the symptom is high pressure, we need to replace the needle with a thicker one.

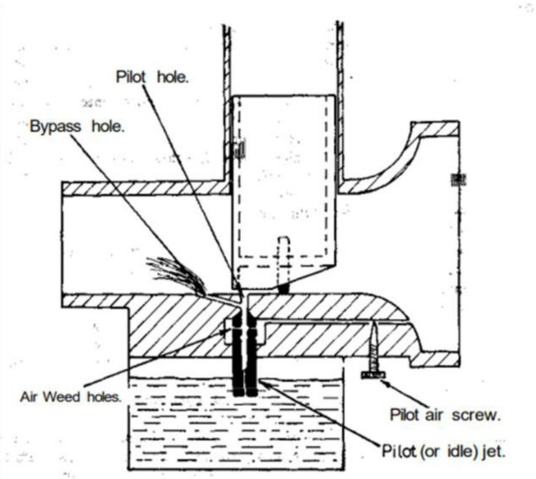


Fig. 5 Idle system operation.

The low-rev setting will always be what keeps the idle as stable as possible, without the bike revving or shaking. This perfect setting will always be when the choke screw is open between one and two turns. If the perfect setting is found with the screw closed, this means we need a larger low-rev jet. Conversely, when the screw is open beyond two turns, we need a smaller low-rev jet. Note in the photo to the side that the low-rev feed is supplied through a bypass . As the gate is closed, there will be a vacuum behind it, and the mixture will rise through a narrow passage. If we switch to a higher-consumption fuel and the idle becomes too high, we may need to enlarge this passage. It typically has an opening of 0.5 mm. For ethanol, it can be opened to 0.6 mm and methanol to 0.7 mm. However, this depends on each carburetor, and the need is only determined after the engine is running.

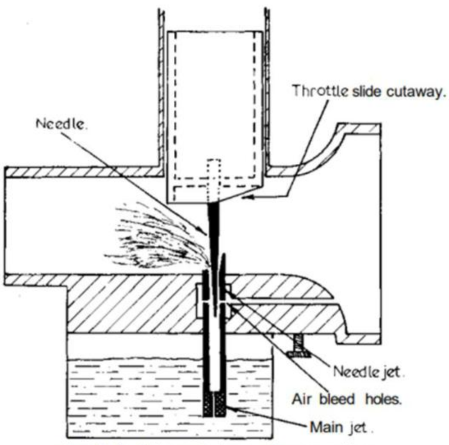


Fig. 5.2 Main metering system operation.

The average setting can be found when we accelerate from 1/4 to 1/2 throttle and the engine doesn't rev up or "spin" too much. What I mean is that the engine can't rev up at all; we must control the engine speed with the accelerator. If the engine revs up on its own without accelerating, it's because the average is lean, requiring the needle to be raised. And if the average is "spinning" too much, the needle must be lowered. The adjustment while the engine is running will be when the engine "spins" without load and when applied, it clears. The engine should never run smoothly when not under load. In this condition, we will notice that the engine will overheat and likely fail. Running "spins", besides cooling the engine, also better lubricates the entire assembly.

This would be a carburetor pre- adjustment while the bike is still stationary. You need to ride the bike and feel the engine constantly "stuttering," and as you accelerate to the point where the engine is working hard, only then will it clear.

Now let's talk about high-rev. It can also be pre-adjusted while the bike is stopped. From half throttle to more, we have a transition from medium to high. Therefore, the two settings blend together. But with 100% throttle, "grip glued," the high-rev jet is in charge.

The first thing to do is, with the bike running, shift from medium to high throttle and check if the throttle grip is held all the way down. From half throttle to 100%

throttle, the engine cannot rev. The engine speed control must always be in hand. We should never have to take our hand off the throttle because the engine has raced.

With engine control in hand, as a tuner friend who taught me this technique would say: "The engine has to be in hand." Referring to this average setting, we can then move on to actually setting the high speed.

We need to "stick the handle" and the engine won't fire. If it doesn't fire, it means we have the right high or fat revs. What we need to do is stick the handle and release our hand and let the engine drop to idle. If it drops to idle perfectly, it's a sign that we have no fault. Assuming here, of course, that the idle is already adjusted. Note that we always start the adjustment at low, then medium, and then high. This is done with the motorcycle still stopped.

If, when you suddenly release your hand, the idle speed rises, this means the high-speed transmission is lean. It's common to think the problem is in the low-speed transmission, but when you release your hand, the crankcase is marked with the high-speed mixture.

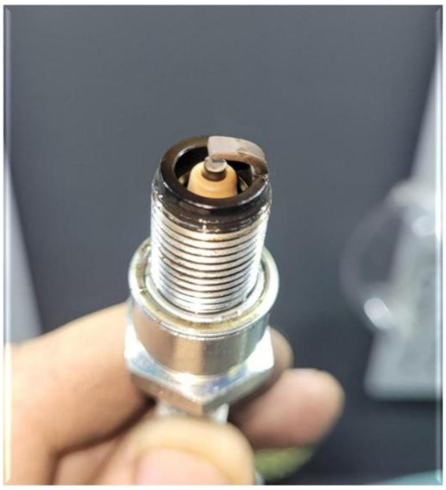
In this case, we need to increase the high-rev jet so that, when we release our hand, the mixture remaining in the crankcase is correct and the idle speed doesn't feel the effects of a lack of high-rev. If the idle speed starts to vibrate or the engine stalls, we probably have a high-rev too high. Therefore, we need to lower the jet.

If we perform these tests correctly and in the sequence presented, we'll have a near-ideal setup. The next step is to actually ride the bike and feel the average and high revs. I've already mentioned what to look for regarding the average.

But high revs are dangerous and require extreme caution. This is where most engine stalling incidents occur. Most people go for an acceleration test to check the spark plug. I have a step before, which is to accelerate to 100%, hold for 3 seconds, and then release my hand. Here again, we'll check if the crankcase has been marked by a lean mixture. When you suddenly release your hand, the engine should drop to idle when the clutch is engaged, or, if in gear, decelerate completely. Here, there should be no sign of the engine wanting to continue revving. It should stall as if we had turned off the master switch. This shows that the mixture remaining from high revs in the crankcase is correct or lean. Repeat this process of accelerating for a few seconds a few times, increasing the time we hold it at 100%. Over time, we gain confidence, and the next step is to monitor the engine temperature.

After all the pre- adjustments and a few longer shots with the grip glued on, always monitoring the temperature, let's check the spark plug. It should start to take on a beige color that tends to brown or brick over time. If it starts to get too dark, the high-rev jet is probably too fat. In this case, lower the high-rev jet one position. After that, continue the tests with the grip glued on, without holding it for too long. This engine is likely breaking in, and it's not a good idea to push it too hard.

We'll perform these tests until we find the ideal spark plug color and then, with confidence, proceed with normal engine use. We won't consider finding a white (dry) or gray spark plug color here. We assume that with the pre- settings, the carburetion will be right to fat (excess fuel).



2.13 Initial considerations on carburetor preparation

Gasoline-powered carburetors rarely need rework. However, avoid using carburetors without first checking their intake flow.

Ethanol carburetors can meet the demand for increased consumption as long as the flow is reworked by at least 50% more flow.

Methanol carburetors cannot meet the increased fuel consumption demand. Even if reworked, they won't meet the 100% increase in flow requirements.

How do you know if a carburetor is suitable? The rule is: add up the flow rates of all jets, including the idle passage. Example: high jet 140, low jet 35, idle passage 40. The total flow rate is 215. This 215 corresponds to 2.15 mm, meaning we need an intake flow of at least 2.8 mm. I usually add an additional 30% to ensure there won't be fuel starvation.

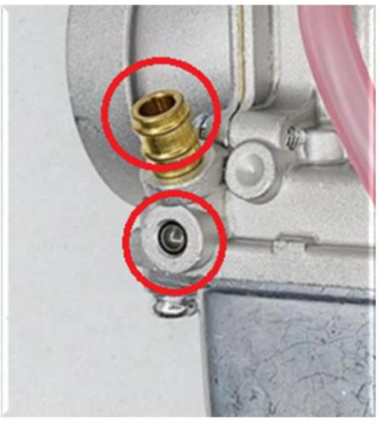
In the table below, we can check the air/fuel ratio (AF) of each fuel and understand how much extra flow we need from each jet. By doing this, we can pre-calculate the jet size to meet the stoichiometric demand of each fuel.

To use ethanol, we'll need to increase the jets by 50%, and for methanol, we'll need to double the jet flow. For example, if I have a 130-valve jet on gasoline, for ethanol, I'll increase the jet size by 50%. In this case, I'd need a 195-valve jet. If I switch to methanol, this jet would increase from 130 (an additional 100%), resulting in a 260-valve jet. Note: These numbers are for reference only. Looking at the table, we can also estimate how much more we'll need to rework the carburetor intake to accommodate the additional demand.

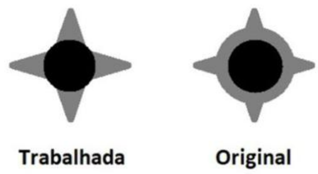
Fuel	AF relationship	Percentage more
Gasoline	14.7	-
Ethanol	9	~50%
Methanol	6.47	~100%

In the photo below, we can measure the inlet flow of the hose connection, and below that, we see the ball that closes the channel leading to the needle inlet. If the flow rate we need exceeds these two inlets, we can rework both. Drill the hose inlet with a drill, taking care not to make the wall too thin.

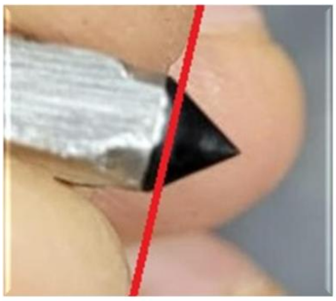
To adjust the flow rate to the needle, we can remove the ball and drill it to the required size. Carefully consider the limit of the opening to avoid opening the passage into the tank and losing the carburetor. Then, we can thread and install a screw to cover the passage where the ball was.



In the images below, we can see the rework on the side of the needle, removing material to increase the flow rate. Be careful not to remove material from the ribs that allow it to slide in the seat. If it becomes loose, it may no longer seal. I usually use a file with a sharp or circular edge, but with a small diameter. Some needles have three and others four sides, but the principle is always the same: remove material up to the diameter of the rubber seal at the tip.



Another important preparation we can make is to increase the needle's passage in the seat. Some seats are removable, and the work can be done externally. However, some seats are made in the carburetor itself. The maximum diameter we can open is by measuring the needle seal and ensuring it will cover the hole. Don't overdo it here; it's easy to damage the carburetor and lose the needle seal. If the largest diameter of the rubber seal is 4 mm, make the hole 30% smaller, or 2.8 mm, as shown in the red line.



Another type of preparation we can make is drilling holes in the needle seat tower. Some carburetors already come with this type of improvement, but others don't. I recommend drilling from the center of the seat inward, that is, closer to the seat's flow hole. This way, when the needle opens, fuel can exit through the holes and not necessarily pass through the needle.

I always recommend using a fuel filter, but always one larger than the one normally used. I usually use automotive filters that have larger connections and filter elements, avoiding restrictions.

Another point we need to pay close attention to is the flow rate of the faucet, nipples , and hoses. Always choose connections with at least 100% more flow than the calculated jet consumption. If we calculate, for example, a consumption of 200, or 2 mm, use at least 4 mm throughout the fuel line.

After opening the seat, there's always a burr on the inside that can prevent a perfect seal. I use the back of any tap that fits perfectly into the seat and, with the help of a drill, grind the inside. The tap has a ground opposite end, and friction polishes the area where the needle seals.

Install the needle and, using a hose, blow through the fuel inlet and test the seal. Repeat the lapping process until the needle seals. Reassemble the carburetor and perform a leak test with fuel. If it doesn't seal, repeat the lapping process.

Pump-type carburetors can also have their flow reworked. The amount the needle passages can be opened follows the same percentage increase concept depending on the fuel. In other words, if the passage is factory-set to 1 mm for gasoline, open it to 1.5 mm for ethanol. However, it's unlikely that it will be able to feed methanol.

This type of rework is more complex because the passages contain seals that need to be carefully removed and reinstalled. I recommend finding a professional who works with this type of carburetor. Kart tuners usually do this or know someone who does.

Because they have a pump that draws fuel, the line flow rate is not so critical, but it is worth keeping it at least 50% higher than the carburetor's inlet.

2.14 Carburetor Flow Rate

To understand proper carburetor setup, it's essential to know how to measure its flow rate. This procedure allows us to determine whether the carburetor can actually deliver enough fuel to the engine under different operating conditions. Simply installing larger jets or adjusting settings isn't enough: if the carburetor's flow capacity isn't sufficient, the engine will run lean at high RPMs and may break down.

The flow test is simple to perform. First, remove the tank's drain plug and connect a clear hose to the outlet. This hose should be directed to a graduated container, such as a graduated cylinder or measuring syringe. With the container ready, open the fuel tap and let the flow run freely for a set amount of time, usually around 10 to 15 seconds.

At the end of this period, we measure the amount of fuel collected. This value gives us the carburetor's actual flow rate in milliliters per second. It's important to repeat the test several times to ensure accuracy, always checking for obstructions in the filter, inlet nipple, or float needle that could interfere with the measurement.

Once the flow rate is known, it must be compared with the engine's demand. Every engine has an approximate fuel consumption based on its displacement, maximum operating speed, and the type of fuel used. For example, gasoline-powered engines consume a certain amount, while ethanol-powered engines require approximately 50% more, and methanol-powered engines consume twice as much. Therefore, the measured flow rate must be sufficient to meet this actual need.

If the volume collected in the test is below expectations, it means the carburetor isn't capable of keeping up with the engine's high-revving demands. In this case, simply increasing the high-revving jet alone won't help, as this will limit the carburetor's fuel supply system. The result will always be a lean engine at high revs, with a high risk of overheating and failure.

In these situations, the solution is to rework the carburetor's internal passages. The fuel inlet diameter can be increased, the needle seat revised, the needle replaced with a higher-flow one, and even the fuel line modified by using larger-diameter hoses, nipples, and taps. In some cases, auxiliary fuel pumps may also be required to ensure the required minimum flow rate.

Another important point is to always perform the flow test with the carburetor assembled exactly as it will be used on the motorcycle, including the float, needle, and all internal components. This ensures that the result reflects actual operating conditions, without overestimating flow capacity.

With the actual measured value and the necessary adjustments made, we can be sure that the carburetor will deliver the correct amount of fuel in all situations. This prevents high-rpm failures, improves engine reliability, and ensures maximum performance is safely achieved.

Below is a table to help you compare the measured flow rate with the required flow rate:

FUEL FLOW TABLE BY GENERATED POWER			
Generated Power	**Fuel type (ml)**		
CV	*Gasoline (all)*	*Ethanol*	*Methanol*
3	20	x	x
5	35	x	x
10	65	95	x
15	100	140	220
20	135	185	290
25	170	240	360
30	200	290	430
40	270	380	570
50	340	480	720
70	470	670	1000
Note: The indicated flow rate is 30% higher than the estimated consumption. Therefore, the flow rate indication already includes a safety margin.			

Note: It's important to note that if the flow rate is higher than that indicated in the table, this suggests that your power supply system is more than sufficient to power your motor. In this case, nothing needs to be done.

Chapter 3 – Fuels

3.1 Introduction

Fuels can be classified in several ways. But for our purposes, I'll separate them into two types as follows:

OXYGENATED – are all fuels that have oxygen in their molecules. Examples include ethanol, methanol, and nitromethane.

NON-OXYGENATED – these are all those that do not have oxygen in their molecules. Gasoline is an example of this.

The presence of oxygen in the molecule explains the stoichiometric ratio of each fuel. This refers to the amount of air required to burn 100% of the fuel. Fuels that contain oxygen require less air to burn, as they contain oxygen itself. This oxygen is removed from the molecule by the pressure and heat of combustion.

In the table below, we can see the AF (air / fuel) ratio, or air/fuel ratio, for each fuel. This means that, for gasoline, for example, we need 14.7 parts of air for 1