find it, we can choose to close it in cases where we're looking for more torque and open it where we're looking for more peak power and higher RPM.

Furthermore, for me, this test is practically inconclusive, since it required opening the engine and there was a very long time interval, perhaps a day, which is known to result in changes in power output. Several times, power output varied by up to 5% from one morning pass to another in the afternoon. Another point to be noted is that the crankshaft balance was altered. It had already been balanced without the acetal bushings that closed the bores, so weight was added at that point. Therefore, I can't guarantee that this test was truly conclusive, but it's clear that this intervention won't change much.

Chapter 14 – Exhaust

14.1 Introduction

Two-stroke engine exhausts come in a variety of shapes, with the earliest ones designed for low-rpm torque and fuel economy. They featured a system that compressed the mixture out of the exhaust port to prevent fuel from being wasted.

Over time, the custom exhaust system was developed, and the entire dynamics of this engine were forever changed. Initially, it was poorly understood, but over the years, it evolved, creating unimaginable functions within the operating dynamics of two-stroke engines.

It's this complexity that makes their operation so interesting. But before falling in love with all these dynamics, we first need to understand how they actually work, so that they can stop being complex and become objects of appreciation.

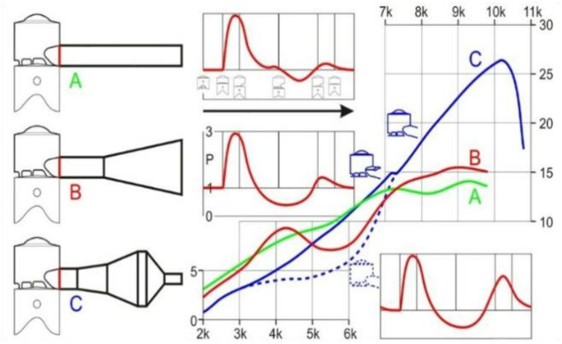
Understanding how they work and how they relate to the engine is where we separate the men from the boys and only then will we look at this remarkable set with the eyes they truly deserve.

Join me on this journey that will show you why I and so many other people love these engines.

14.2 Formats

The exhaust shape dictates the engine's operating rules. Below we see three examples of exhausts and their respective pressure curves. The only similarity is that they all have headers.

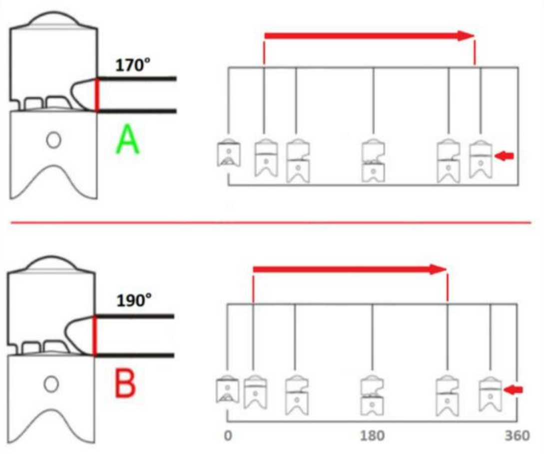
We have the straight pipe represented by the letter A, we also have the straight pipe with just the diffuser represented by the letter B and the complete exhaust represented by the letter C. Each of them has a different characteristic.



14.3 Shock waves

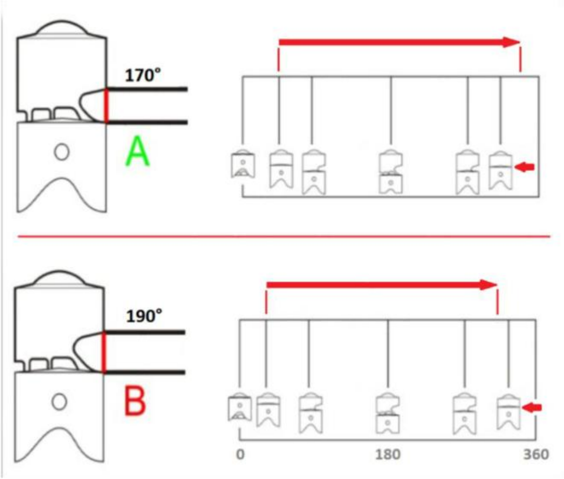
To understand how the shock wave affects engine dynamics, let's use a didactic example with two engines rotating at the same RPM and with equal exhaust lengths, represented by the red line. The difference between them is the height of the exhaust port, which in engine **A** has 170 degrees (lowest) and in engine **B** it has 190 degrees (highest).

If the wave exits window B first because it's taller and the exhausts are the same length, this means the shock wave will return to the cylinder before it does in engine A, which emitted the pulse later. This means the engine RPM benefits the return of the wave when engine A is almost closing the exhaust port, aiding in supercharging. On the other hand, engine B is receiving the shock wave too early, which doesn't benefit the power gain.



To make it even clearer, let's reverse the situation now, using a higher RPM. Note in the figure below that the exhaust delivers the shock wave just before engine B closes its exhaust port, aiding in its supercharging. In engine A, the shock wave arrives too late, when the piston would have already closed the exhaust port and prevented the pulse from entering.

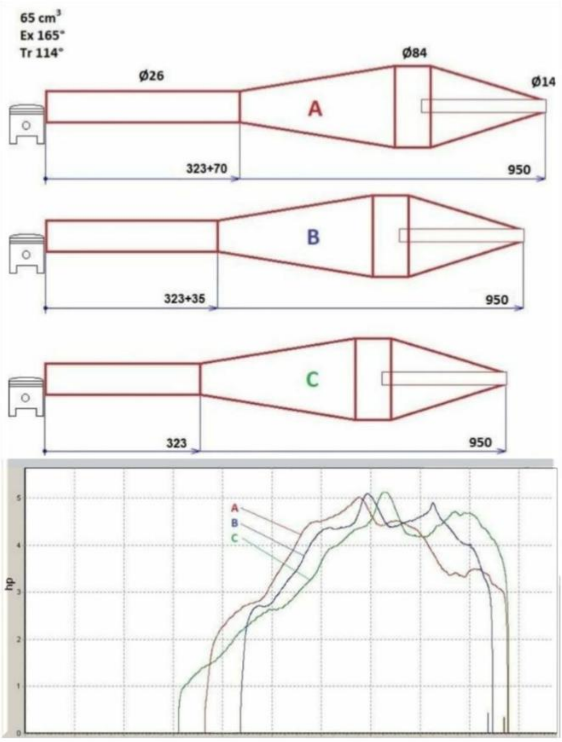
This pulse entry timing issue can be corrected by changing the piston speed, i.e., increasing or decreasing the engine speed. In the case shown, simply make engine A spin slower to take advantage of the pulse arrival while the piston is still open. We can also correct this issue by changing the exhaust length.



This is why an engine's RPM range changes when we adjust the exhaust port. Lower exhaust port settings take advantage of the return wave at lower rpm, and higher exhaust port settings take advantage of the return wave at higher rpm.

If we want to make corrections to the RPM range of any engine, we can change the exhaust length in order to tune the return shock wave to match the useful RPM range we desire.

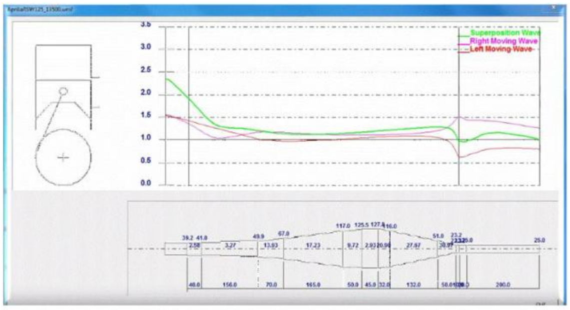
Many parameters can be adjusted for best overall performance, as suggested by the tuner method, but many things can be readjusted or redirected once we know what we're doing. Below, we can see the power curve correction simply by lengthening the header of completely similar exhausts.



14.4 Secondary waves

As we've already understood, each time the exhaust port opens, a pulse is sent to the exhaust. Whenever this wave returns at the wrong time—that is, when the piston is closing the wave's entry into the cylinder—it rebounds and returns to the exhaust, beginning a new back-and-forth path. Of course, it loses strength, but it still contributes to the engine's operating dynamics.

If it returns and coincides with the main wave that was emitted by the last combustion cycle, they add together and generate an even stronger wave, amplifying the engine's efficiency even further.

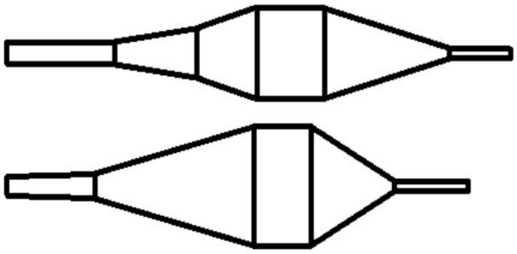


14.4 Myths

Volume: One of the biggest myths about exhausts is that measuring their volume and comparing it to another's will give you a specific parameter. "Literature," as we hear it called, doesn't tell you anything about an exhaust because the geometry of both can be different, and this is what determines the engine's performance.

Below we see two exhausts with the same internal volume, that is, if we fill one exhaust with water and pass the same amount of water to the other exhaust, it will also be full.

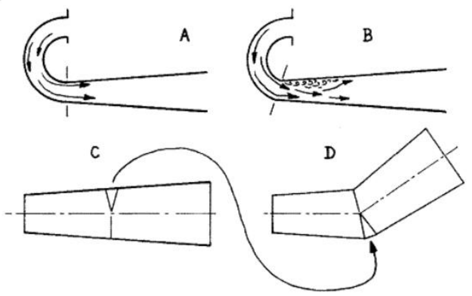
Some tuners use this technique as a comparison, but as we will see in this module, the exhaust volume is linked to the strategy we want for the engine and that this volumetric capacity of the exhaust changes drastically depending on the application it will perform.



Curves: Curves don't impede or affect the shockwave. On the contrary, according to reports on the development of the Aprilia RSA exhaust, the curved exhaust performed as well as a straight exhaust.

Shock waves don't care about curves since they're not made of matter but of energy. They're not like gases, which are made of molecules and particles that can rub against the exhaust pipe walls.

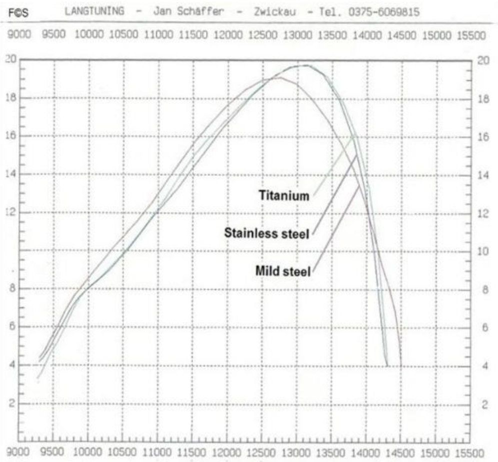
The only thing to avoid are sharp corners, as these reflect the wave and cause it to disperse in its direction. Using rounded beams is always the best option.



Muffler: We often see tuners removing the muffler from their exhausts in an attempt to improve their engine's performance. But the fact is, if the muffler is built correctly, that is, with a larger dimensional relief than the stinger, there won't be any restrictions. Therefore, it's a myth that we'll experience power loss with a properly sized muffler. Just look at the most successful engines ever built.

14.5 Building materials

By FOS (Frits Overmars): This graph shows the effect of exhaust gas temperature, influenced by the different density, specific heat, and thermal conductivity values of mild steel, stainless steel, and titanium, in three exhaust pipes with identical dimensions. The three power curves were measured on the same engine, with identical fuel, engine settings, and temperatures, on the same dynamometer, and on the same day. The different materials were the only variable.



This graph shows the effect of exhaust gas temperature, influenced by the different density, specific heat and thermal conductivity values of mild steel, stainless steel and titanium, in three exhaust pipes with identical dimensions. The three power curves were measured on the same engine, with identical fuel, settings and engine temperatures, on the same dyno on the same day. The different materials were the only variable. F©S

14.6 Supercharging

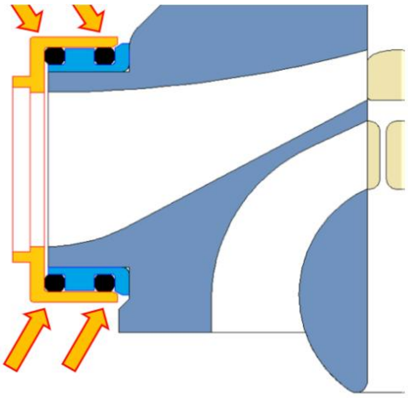
As we've seen so far, the exhaust has several functions, such as helping to admit more mixture from the crankcase to the cylinder, helping to clean the burnt gases, returning the mixture that ended up in the header, and even pressurizing the engine to increase its volumetric efficiency. In other words, making it even larger than it actually is. Just as a turbo works in a four-stroke engine, pushing more air/fuel into a volume that would only fit 100% of the chamber's total capacity. The more pressure we can push back into the engine before the exhaust port closes, the greater the power the engine can generate, since more fuel will actually be burned. Essentially, powering an engine means making its displacement larger than it actually is.

In two-stroke engines, we can reach 0.5 kg/f or even more, depending on the workload and the combination of primary and secondary waves. Imagine that a 100cc engine with 0.4 kg/f can be equivalent to a 140cc engine.

14.7 Exhaust sealing

We already understand that we have negative pressure (vacuum) that allows mixture to enter the crankcase and positive pressure, which is vital for engine supercharging. Any leak between the exhaust and the cylinder flange will result in power losses. Some exhausts have very tight flanges, others have Viton rings , and others simply have a cylinder cap with a conical exhaust port. All types, provided they are well-constructed, will provide a good seal.

However, I always suggest pre-assembling the exhaust and placing the piston at TDC. After blowing the opposite end of the exhaust, check for leaks at the nozzle-to-cylinder joint. Often, a small leak occurs, and the engine's vibration adjusts the parts, stopping the leak. However, if this small leak persists over time, it's recommended to investigate what's wrong and preventing a perfect seal. Holes anywhere in the exhaust also impair its proper functioning, whether in the header, diffuser, belly pan, or baffle .



14.7 Flange

As we've discussed before, the exhaust flange needs to have the best possible seal. Vacuum and pressure are constantly acting there, and if the connection isn't good, we'll lose power.

The IAME flange uses a conical flange that, through springs, forces the exhaust coupling. The more pressure exerted on the spring, the better the seal. This type of flange tends to improve sealing with engine vibration, as the friction between the two forms the joint.

14.9 Sections – Header

The header seems to be a useless part of the exhaust and is usually built without the length, diameter or progression it should have.

The consensus is that it should have a diameter between 15 and 20% larger than the exhaust port. Therefore, we now have a foundation for building the beginning of the header. We need to understand that it plays a crucial role in providing time for all the pressure from the burnt gases to escape and lower the pressure in the exhaust port before the shock wave enters the diffuser and effectively initiates the reverse shock wave, so important for cylinder filling.

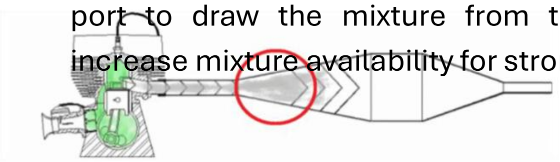
The header must be long enough (time x) to exhaust all the combustion pressure before we send the suction wave created by the next section, the diffuser.

It should have a certain taper, but this progression cannot be so wide that it mimics the diffuser's function of creating a vacuum wave too early. If we create a vacuum wave too early, it will clash with the exhaust pressure, which in turn will cancel itself out, and we won't get the much-desired vacuum entering through the exhaust port.

Fritz illustrated this effect as a bird trying to fly in a storm; it won't win. However, it's important that the header has a certain progression of diameter increase as it moves away from the exhaust port, precisely so as not to create a restriction on the outflow of gases. This progression should be around 1.5 to 3 degrees.

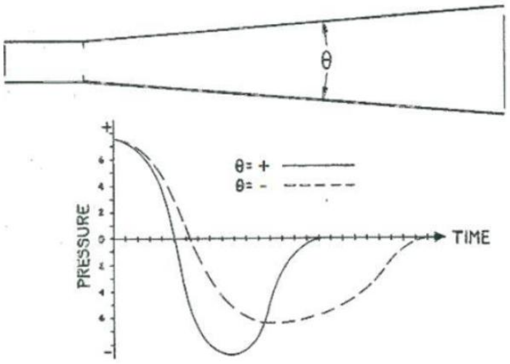
14.10 Sections – Diffuser

As discussed previously, the diffuser plays a vital role in power generation, as it participates in the engine's fueling phase. It creates suction in the exhaust port to draw the mixture from the crankcase and increase mixture availability for stronger combustion.



As the shock wave exits the header and enters the conical part of the diffuser, the gases are forced to expand as they pass through increasingly larger sections towards the belly.

This sudden expansion creates a negative pressure wave behind the shock wave, which travels toward the exhaust port and back up the header. Here, the header's progression aids the rise of the vacuum wave.



However, we can change the angle of the diffuser to create a narrower or more widespread suction wave. Just as we consider all of our motor adjustments, let's consider the diffuser with the strategy we want to use it.

The more open the diffuser, the higher the suction wave peak, generating a high-amplitude but short-period wave. This means a powerful wave that benefits a very narrow rotational range.

A more closed diffuser, on the other hand, generates a smoother, longer-period wave that spreads the torque zone across a wider range of the power curve. We'll see 7-degree diffusers on motocross exhausts and 18-degree diffusers on road racing and 201-meter exhausts.

Here, we'll always be tempted to seek more power by using more open diffusers. But we can't use this strategy at the expense of the pursuit of power. An engine with a wide diffuser angle exhaust used in everyday use would be practically unviable. It would be an engine with a very narrow power band. And that's why we see exhausts with bellies of larger and smaller diameters, since the angle of the diffuser, as a function of its length, will determine which diameter it will end in and connect to the bellie.

That's why I want to disabuse you of the notion of how voluminous an exhaust is or isn't. The angle of the diffuser dictates the desired performance for the design, and how "fat or thin" the exhaust is much more a function of the diffuser's taper than the exhaust volume itself.

Motocross bikes have a shallow diffuser angle to maximize the powerband. Racing bikes have a steeply angled diffuser to generate peak power.

Therefore, the angle of the diffuser and how voluminous the belly pan will be is a function of the design strategy and the adjusted length. In other words, how and where we want the engine's powerband to be positioned.

14.11Sections – Belly

The belly is a neutral zone in the exhaust. It exists so that primary and secondary waves can intersect without canceling each other out. We typically use it to adjust the required length by increasing or decreasing its length.

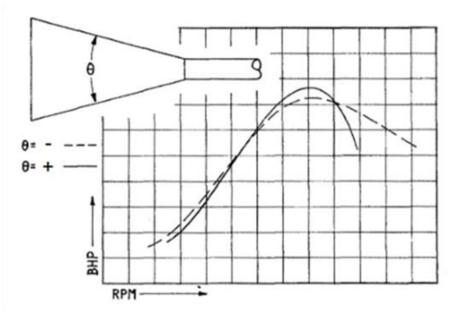
This is why we see longer exhaust pipes on engines with low-RPM torque bands and shorter pipes on high-RPM exhausts. The pipe diameter is a consequence of the engine displacement and the initial diameter of the header. But as explained in the diffuser section, the pipe diameter is much more tied to the desired engine behavior than anything else.

14.12 Sections - Baffle

The baffle is another crucial cone in engine performance and how we approach our tuning strategy. It's responsible for reflecting and returning the shock waves emitted by the exhaust port.

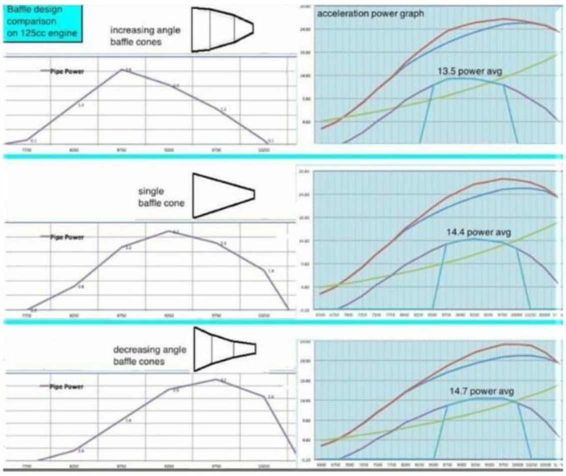
But unlike the diffuser that shapes the vacuum wave, the baffle shapes the shock wave that returns the lost mixture charge to the exhaust port and supercharges the engine.

In the same way that we learned to shape the shock wave as it leaves the exhaust port, we can also shape it in the deflector cone even further, bringing different characteristics to the power curve according to our needs.



If our strategy is to spread the powerband by creating a more arched exhaust port, we can spread it even further by reducing the opening angle of the deflector cone. This is why we see motorcycles with gearshifts featuring very long, shallow deflectors. Similarly, we see racing scooters using short, open exhausts, seeking to concentrate the powerband in a very narrow range and generate peak power.

As we see in the photo below, open cones create a high power range and kill the engine right at peak. Open cones, on the other hand, extend the powerband after peak. We'll see 20- to 24-degree cones in exhausts that spread the curve, just as we'll see 29- to 32-degree cones in exhausts that concentrate the powerband.

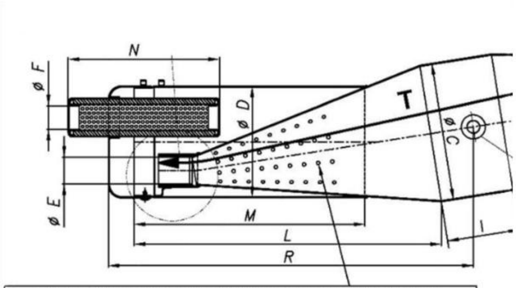


In addition to taper, we can create deflector cones with sections and further shape the power curve.

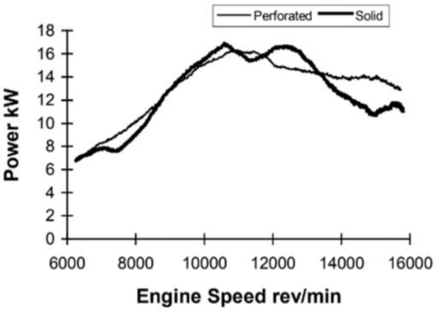
Concave cones tend to bring the power curve before peak power. Straight cones tend to have a more linear curve. Convex cones push the power band to higher RPMs, generating even more power.

Gordon Blair conducted an experiment with a 100cc direct-drive kart engine and tested two identical exhausts. The only difference was that one of them had a perforated exhaust, under identical testing conditions, on the same day, at the same temperature. The power curve below shows the difference in the holes, spreading the power curve from low to high RPM.

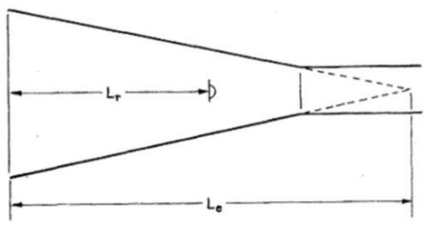
The result is that the drilled baffle was able to accelerate the inertial dynamometer from 6250 rpm to 15,500 rpm in 4.49 seconds. While the baffle without holes accelerated in 4.79 seconds. IAME recommends for this application a total of 72 3mm holes spread out from the middle of the baffle.



N° 8 ROWS OF HOLES. THE ROWS ARE COMPOSED OF N°9 HOLES Ø3, FOR A TOT OF 72 HOLES. THE HOLES HAVE A TOLLERANCE OF ±0.2



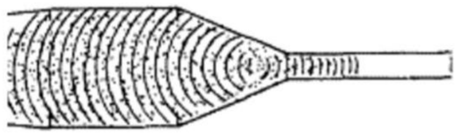
The baffle is our wave reflector, and it's purposefully not a straight wall so it doesn't return a shock wave that's too short. It's conical so we can shape the shock wave to our needs. However, since it's a cone, where do we actually consider the end of the exhaust?



We will always consider the end of our adjusted length to be the middle of the cone, which is the average reflection of the shock wave. However, the middle of the cone does not end when it connects to the stinger (the pipe at the end of the exhaust).

We need to draw an imaginary line from where the cone would actually end if it were closed and only then will we have the total length of the cone to define its middle.

14.13 Sections - Stinger



The stinger is the exhaust pressure adjustment point. Its function is to maintain the pressure at the correct level so that there is pressure against the exhaust port and prevents mixture loss through the exhaust port. This pressure acts as a physical barrier, "sealing" the cylinder opening.

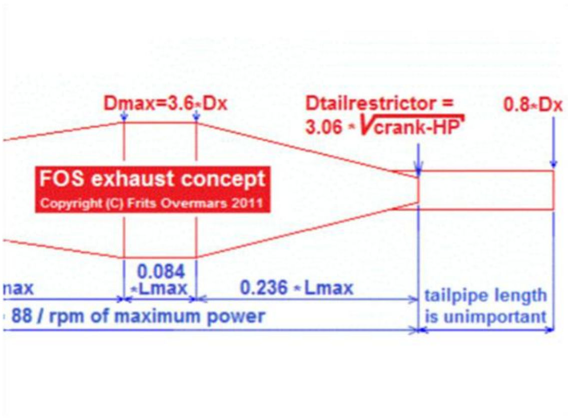
However, there is a limit to how much we can increase the pressure and create this barrier, since the pressure is directly linked to the increase in internal temperature of the exhaust and consequently inside the cylinder.

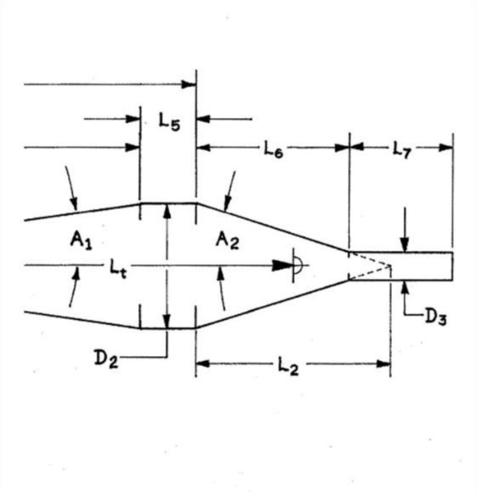
A stinger that's too narrow can overheat the piston crown and even result in a hole if signs of overheating aren't noticed beforehand. However, a sufficiently narrow and well-sized stinger delivers power across the entire power curve.

There is an average of how much can be restricted and it is between 0.57 to 0.62 of the diameter of the header, that is, the exhaust inlet.

But I recommend always starting with the largest size and then tightening it down. The ideal size will generate good power, and tightening it down more than necessary will only heat up the engine.

To know the correct measurement, the ideal is to use a dynamometer, otherwise it is better to lose a little power than to end up with a punctured piston.





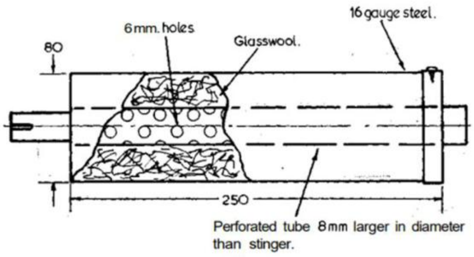
There are two ways to restrict the stinger.

The first is to create a restriction right at the exit of the baffle, and the stinger continues with a larger diameter, without causing a restriction. This method is suggested by FOS.

The second approach is to create a long tube that creates a restriction along its entire length, since a long, straight tube imposes a restriction the longer it is. This second method is suggested by all other known authors.

I personally prefer the FOS restriction method because it seems more realistic to think of a single restriction rather than the extent to which a longer or shorter tube restricts. Plus, you can create a ring-shaped restrictor embedded in the larger diameter stinger and replace it whenever you want.

14.14 Sections - Silencer



As already explained, the silencer should not alter the engine's power characteristics, as long as it is well constructed.

According to Graham Bell, the muffler should be around 8mm wider in diameter than the stinger . This allows exhaust gases to pass through the muffler, leaving the exhaust system unaware of anything behind the stinger . It should be constructed with a perforated tube and lined with fiberglass or rock wool, which has greater resistance.

The longer the length, the greater the noise reduction effect it can have. However, if the length exceeds 250 mm, it is recommended to increase the diameter difference between the perforated pipe and the stinger to avoid restriction.

14.15 Torque Range Calculation

I tested several exhaust length calculation formulas trying to figure out the maximum torque peak and the Graham Bell, Gordon Jennings and FOS equations are the ones that seemed most realistic to me.

In my tests, I found Graham Bell's formula to be a good fit for length when compared to engines where I had data such as exhaust port graduation, total pipe length, and highest peak torque RPM. In the calculation we'll see below, I found a very small difference between the two formulas, to be considered negligible (1 cm in exhaust length).

Using Jennings' formula, which assumes a standard shock wave velocity, I was able to more closely approximate the calculated data with data from known engines. Therefore, this is the formula we will adopt for our application.

soon relate Jennings' formula to the specifications of the Aprilia RSA, which is the project from which we have the most and most reliable data possible to prove the numbers we want to validate.

Gordon Jennings Formula:

$$L_t = \frac{E_o \times V_s}{N}$$

Where:

- **L** $_t$ is the tuned length, in inches
- **E** $_o$ is the open escapement period, in degrees
- **V** $_s$ is the wave speed, in feet per second
- **N** is the crankshaft speed, in revolutions per minute

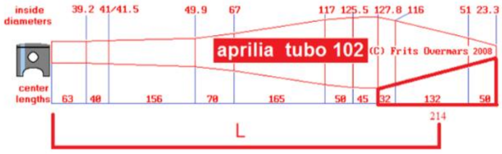
Graham Bell's formula:

$$L = \frac{ED \times 42545}{rpm}$$

Where:

- **L** = adjusted length in millimeters (mm)
- **DE** = duration of exhaustion in degrees

- **rpm** = engine speed (at which the exhaust is adjusted for best operation)



Now that we have a formula to base ourselves on, let's put it to the test to validate its effectiveness. But first, let's familiarize ourselves with the terms in the formula. The letter L represents the length of the exhaust from the piston edge to the middle of the last cone (baffle). This is the path the wave travels to and from the cylinder.

In the formula, the unit L is inches, but simply multiplying it by 25.4 gives the measurement in millimeters. In calculations, we'll always use inches.

The letter E represents the angle of our escapement in degrees, measured with the graduated disc. Here, for our example, we'll use the RSA data, which, as we've already seen, used 202 degrees.

The letter V is a shock wave velocity constant in feet per second, so we will use the value of 1700 suggested by Jennings in our calculation.

The letter N represents the crankshaft speed at the moment of greatest engine torque, which in the case of the RSA reached 12517 RPM with a maximum of 29.75 Nm.

With all this data, we can calculate:

Data taken from the Aprilia RSA 125 engine

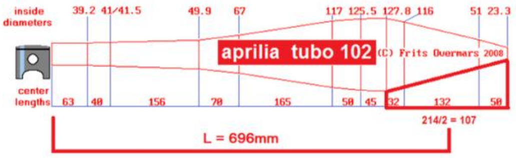
Exhaust Port Timing	202° geometric

Torque	29,75 Nm @ 12517 rpm

Therefore:

$$\boxed{L = \frac{202 \times 1700}{12517}} = \boxed{L = \frac{343.400}{12517}} = \boxed{L = 27{,}43}$$

$$\boxed{L = 27{,}43 \times 25{,}4 = 696{,}8\text{mm}}$$



Now that we know the adjusted exhaust length, we must compare the measurement found with the actual exhaust that RSA used.

We have to measure the length from the edge of the piston to the middle of the baffle , which is the last cone.

The baffle was made up of three sections that, when added together, gave a length of 214 mm. Therefore, half of this would be 107 mm. This will be the length we use in the total calculation.

Therefore, we will have: 63+40+156+70+165+50+45+107 = **696mm**

Is it a coincidence that we found such a precise number? Or can we consider that we have a pattern and a formula very close to reality to follow?

With the formula validated, a world of possibilities opens up. We can make variations on it to discover:

1. the torque range generated by the exhaust in conjunction with the height of the cylinder exhaust port;

2. change the exhaust port graduation and find out what RPM the engine will generate the most torque at;

3. Tune the exhaust port or exhaust to the best working range of our shift system.

$$L_t = \frac{E_o \times V_s}{N}$$

We can transform the formula to find the exhaust length if we have the exhaust port graduation:

$$N = \frac{E \text{ x } V}{L}$$

Therefore:

$$N = \frac{202 \text{ x } 1700}{27{,}43} \quad N = \frac{343.400}{27{,}43} \quad N = 12.519$$

And we can also find out the exhaust port graduation if we have the exhaust length.

$$E = \left(\frac{L}{V}\right) x\ N$$

Therefore:

$$E = \frac{27{,}43}{1700}\ x\ 12.519 \qquad E = 201{,}99$$

14.16 The formulas

Note that we used Gordon Jennings' formula to calculate the adjusted exhaust length and validated this data against a real design. Therefore, the adjusted length will be our reference point. However, this data only tells us where peak power will be, not how it is allocated to the engine's power curve. We also know that exhaust temperature changes the exhaust adjusted length calculation, but we can use it as a good reference point when choosing or designing an exhaust. It's not precise, but it's much better than being in the dark.

Very important: we need to understand here that the exhaust calculation formulas we can use will always direct us to a specific exhaust type. The FOS formula, for example, is based on the development of the Aprilia RSA exhaust, and that this motorcycle's application was for high-speed closed-circuit racing.

Understanding that this application won't work on a street engine, for example, is what will differentiate the enthusiast from the professional tuner who knows what they're doing and is convinced of the strategy required for the project. Understand that the opening angles and cross-section diameters dictate the exhaust pipe's behavior and will radically alter the engine's usability, as we've seen in several stages of our study so far. Everything is interconnected, and considering the project's strategy is more important than ever when choosing or building the exhaust we'll use.

Therefore, we will base ourselves on the data suggested by FOS for the development of high-performance exhausts, knowing that the total length and proportionality between the dimensions of all sections bring dynamics as close to ideal as possible when we think about performance.

In the FOS formula, the header accounts for 34%, the diffuser 32%, and the belly plus baffle 34% of the total length. This ratio seems like a good starting point for a high-performance exhaust, but we'll see throughout this module that this ratio can change depending on the application.

What I want you to understand here is that when you use any formula to build an exhaust, you're limiting yourself to the behavior that the generated design will provide. This thinking completely contradicts the tuning method, which seeks to direct the design of all tuning features in a direction that maximizes the efficiency of two-stroke engines.

Imagine you're designing an engine for everyday use and considering a more arched exhaust port, selecting a grade from our table on the light tuning scale. Let's imagine you want to develop an exhaust for this project, and that the exhaust has to keep up with the idea that this engine needs torque across a broader powerband. Assuming you choose the FOS formula to develop the exhaust, the result would be disastrous. Your engine trying to spread the band, and your exhaust trying to concentrate.

In the same way, we might want an engine for a 201m sprint and use Gordon Blair's formula, which clearly seeks to spread the power band.

That's why I want to disassociate you from the formulas unless they serve the desired purpose. However, we will discuss, compare, and illustrate various types of exhausts here so there's no doubt about the practical impact each section, diameter, or opening angle has on the pipe's performance.

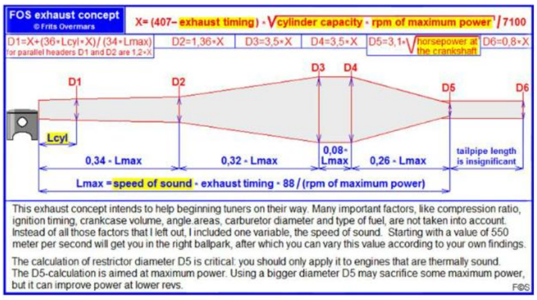
14.17 FOS Formula

As I mentioned before, when we think about high-performance exhausts, we will use the FOS formula.

Here, we'll use the dimensions he suggested to measure all exhaust sections. FOS cites a total length up to the stinger, but we'll use the adjusted length we've already learned to calculate as the basis for the calculation. The formula considers the Lmax value to calculate all lengths and X for all diameters. But before we actually begin the calculations, we need to understand that two-stroke engine exhausts increase the engine's volumetric efficiency.

We know that volumetric efficiency follows the torque curve, and that will be our target in this study. Therefore, we will base the study on the engine's highest torque RPM. Let's open the PDF that will be made available and validate the formula with the calculations.

The FOS formula:



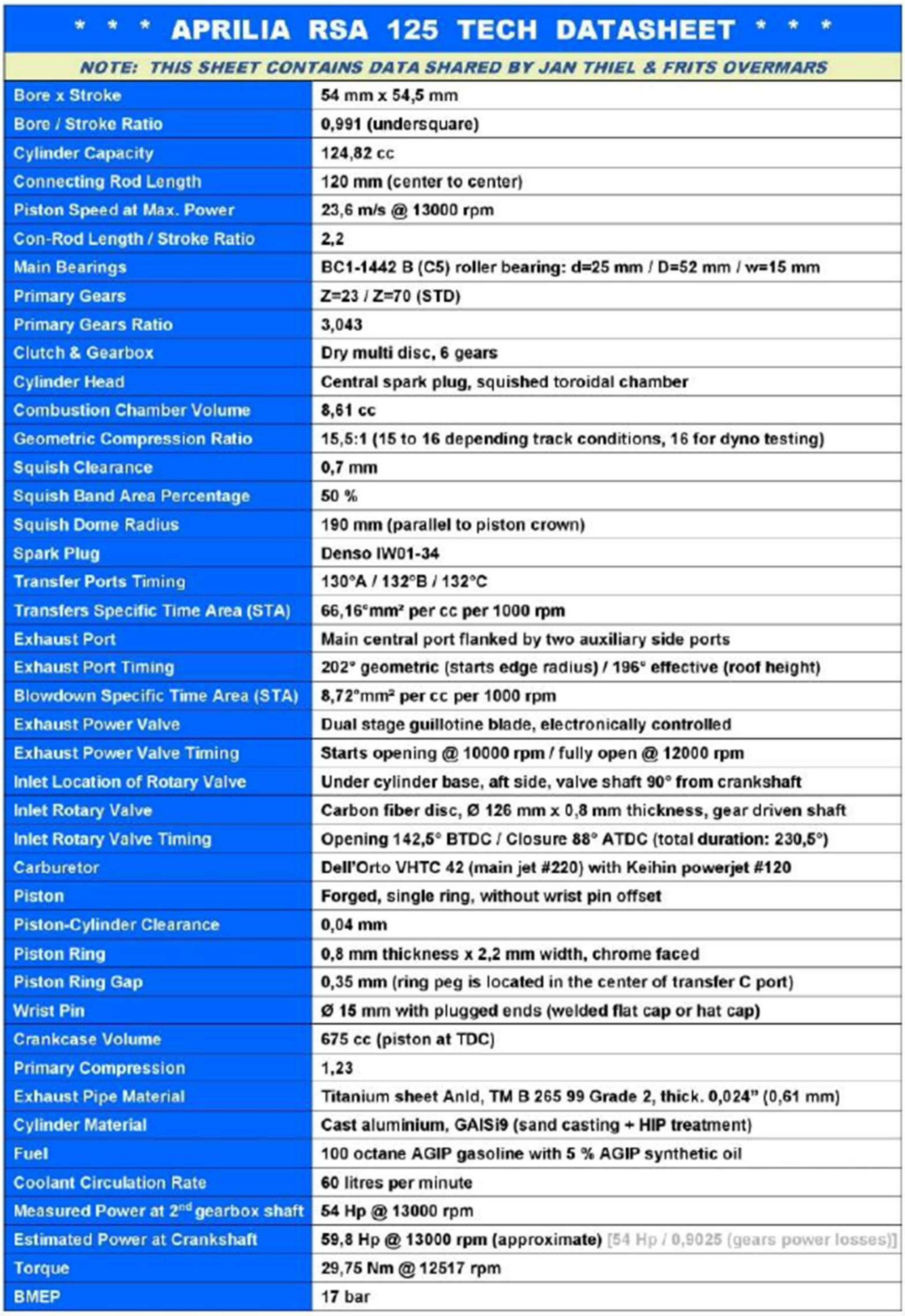
This exhaust concept intends to help beginning tuners on their way. Many important factors, like compression ratio, ignition timing, crankcase volume, angle.areas, carburetor diameter and type of fuel, are not taken into account. Instead of all those factors that I left out, I included one variable, the speed of sound. Starting with a value of 550 meter per second will get you in the right ballpark, after which you can vary this value according to your own findings.

The calculation of restrictor diameter D5 is critical: you should only apply it to engines that are thermally sound. The D5-calculation is aimed at maximum power. Using a bigger diameter D5 may sacrifice some maximum power, but it can improve power at lower revs.

FOS formula Overmars is the latest in exhaust calculations for 2-stroke engines.

How to use the formula:

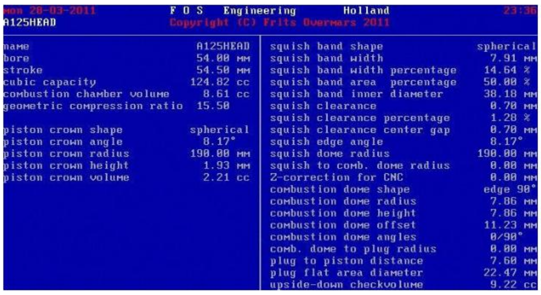
To ensure our calculations are accurate, let's validate the numbers against the Aprilia RSA GP125cc parameters, from which we have all the engine/exhaust data and the power curve measured on a dynamometer. Below is the technical sheet with all the data we'll use in our calculations.



* * * APRILIA RSA 125 TECH DATASHEET * * *

NOTE: THIS SHEET CONTAINS DATA SHARED BY JAN THIEL & FRITS OVERMARS

Bore x Stroke	54 mm x 54,5 mm
Bore / Stroke Ratio	0,991 (undersquare)
Cylinder Capacity	124,82 cc
Connecting Rod Length	120 mm (center to center)
Piston Speed at Max. Power	23,6 m/s @ 13000 rpm
Con-Rod Length / Stroke Ratio	2,2
Main Bearings	BC1-1442 B (C5) roller bearing: d=25 mm / D=52 mm / w=15 mm
Primary Gears	Z=23 / Z=70 (STD)
Primary Gears Ratio	3,043
Clutch & Gearbox	Dry multi disc, 6 gears
Cylinder Head	Central spark plug, squished toroidal chamber
Combustion Chamber Volume	8,61 cc
Geometric Compression Ratio	15,5:1 (15 to 16 depending track conditions, 16 for dyno testing)
Squish Clearance	0,7 mm
Squish Band Area Percentage	50 %
Squish Dome Radius	190 mm (parallel to piston crown)
Spark Plug	Denso IW01-34
Transfer Ports Timing	130°A / 132°B / 132°C
Transfers Specific Time Area (STA)	66,16°mm^2 per cc per 1000 rpm
Exhaust Port	Main central port flanked by two auxiliary side ports
Exhaust Port Timing	202° geometric (starts edge radius) / 196° effective (roof height)
Blowdown Specific Time Area (STA)	8,72°mm^2 per cc per 1000 rpm
Exhaust Power Valve	Dual stage guillotine blade, electronically controlled
Exhaust Power Valve Timing	Starts opening @ 10000 rpm / fully open @ 12000 rpm
Inlet Location of Rotary Valve	Under cylinder base, aft side, valve shaft 90° from crankshaft
Inlet Rotary Valve	Carbon fiber disc, Ø 126 mm x 0,8 mm thickness, gear driven shaft
Inlet Rotary Valve Timing	Opening 142,5° BTDC / Closure 88° ATDC (total duration: 230,5°)
Carburetor	Dell'Orto VHTC 42 (main jet #220) with Keihin powerjet #120
Piston	Forged, single ring, without wrist pin offset
Piston-Cylinder Clearance	0,04 mm
Piston Ring	0,8 mm thickness x 2,2 mm width, chrome faced
Piston Ring Gap	0,35 mm (ring peg is located in the center of transfer C port)
Wrist Pin	Ø 15 mm with plugged ends (welded flat cap or hat cap)
Crankcase Volume	675 cc (piston at TDC)
Primary Compression	1,23
Exhaust Pipe Material	Titanium sheet Anld, TM B 265 99 Grade 2, thick. 0,024" (0,61 mm)
Cylinder Material	Cast aluminium, GAlSi9 (sand casting + HIP treatment)
Fuel	100 octane AGIP gasoline with 5 % AGIP synthetic oil
Coolant Circulation Rate	60 litres per minute
Measured Power at 2nd gearbox shaft	54 Hp @ 13000 rpm
Estimated Power at Crankshaft	59,8 Hp @ 13000 rpm (approximate) [54 Hp / 0,9025 (gears power losses)]
Torque	29,75 Nm @ 12517 rpm
BMEP	17 bar



```
mon 28-03-2011              F O S   Engineering       Holland                  23:36
A125HEAD                    Copyright (C) Frits Overmars 2011

name                           A125HEAD  squish band shape                  spherical
bore                           54.00 mm  squish band width                    7.91 mm
stroke                         54.50 mm  squish band width percentage        14.64 %
cubic capacity                124.82 cc  squish band area  percentage        50.00 %
combustion chamber volume       8.61 cc  squish band inner diameter          38.18 mm
geometric compression ratio  15.50       squish clearance                     0.70 mm
                                         squish clearance percentage          1.28 %
piston crown shape            spherical  squish clearance center gap          0.70 mm
piston crown angle              8.17°    squish edge angle                    8.17°
piston crown radius           190.00 mm  squish dome radius                 190.00 mm
piston crown height             1.93 mm  squish to comb. dome radius          0.00 mm
piston crown volume             2.21 cc  Z-correction for CNC                 0.00 mm
                                         combustion dome shape             edge 90°
                                         combustion dome radius               7.86 mm
                                         combustion dome height               7.86 mm
                                         combustion dome offset              11.23 mm
                                         combustion dome angles               0/90°
                                         comb. dome to plug radius            0.00 mm
                                         plug to piston distance              7.60 mm
                                         plug flat area diameter             22.47 mm
                                         upside-down checkvolume              9.22 cc
```

```
mon 18-02-2013              F O S   Engineering       Holland                  01:28
                            Copyright (C) Frits Overmars 2012

                          maximum power   (hp)
                          A-RSA125 54.00 13007
```

The formula suggests that we find two constants, X and Lmax . From these two constants, we can find all the other dimensions of the exhaust.

Discovering X:

The formula for X is:

X = (407 – Escape Window Time) x $\sqrt{cilindrada\ cúbica\ x\ RPM}$/7100

Let's apply the known data from the Aprilia RSA:

X = (407 – 202) x $\sqrt{125\ x\ 13.000}$/7100

X = 205 x $\sqrt{1.625000}$/7100

X = 205 x 1274.75 / 7100

X = 36.8

Finding Lmax :

The formula for Lmax is:

Lmax = speed of sound x exhaust port time x 88/RPM

FOS suggests starting with the speed of sound of 550 m/s.

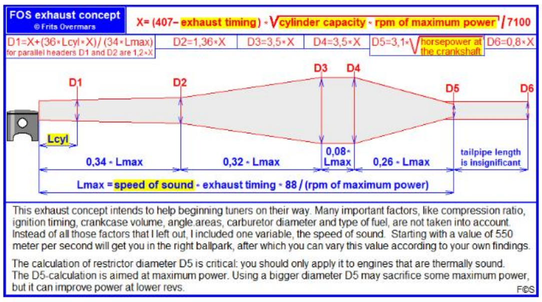
Let's apply the known data from the Aprilia RSA:

Lmax = speed of sound x exhaust port time x 88/RPM

Lmax = 550 x 202 x 88 /13,000

Lmax = 763.2mm

With the values of X and Lmax we can calculate all the dimensions of the exhaust according to the formula:



This exhaust concept intends to help beginning tuners on their way. Many important factors, like compression ratio, ignition timing, crankcase volume, angle.areas, carburetor diameter and type of fuel, are not taken into account. Instead of all those factors that I left out, I included one variable, the speed of sound. Starting with a value of 550 meter per second will get you in the right ballpark, after which you can vary this value according to your own findings.

The calculation of restrictor diameter D5 is critical: you should only apply it to engines that are thermally sound. The D5-calculation is aimed at maximum power. Using a bigger diameter D5 may sacrifice some maximum power, but it can improve power at lower revs.

Header diameter D1

D1 = X + (36 x Cylinder Duct Length (Lcyl) x X) / (34 x Lmax)

D1= 36.8 + (36 x 63 x 36.8) / (34 x 763.2)

D1= 36.8 + (83.462 / 25,948.8)

D1 = 36.8 + 2.21

D1= 40.01

Header diameter D2

D2 = 1.36 x X

D2 = 1.36 x 36.8

D2= 50.04

Diffuser Diameter D3

D3 = 3.5 x X

D3 = 3.5 x 36.8

D3= 128.8

Diffuser Diameter D4

D4 = 3.5 x X

D4 = 3.5 x 36.8

D4= 128.8

Stinger (restrictor) diameter D5

D5 = 3.1 x√푲퓟

D5 = 3.1 x√59,8

D5 = 3.1 x 7.73

D5= 23.97

Stinger (tube) diameter D6

D6 = 0.8 x X

D6 = 0.8 x 36.8

D6= 29.44

With the value of Lmax we will calculate all lengths:

Header Length: 0.34 x Lmax

0.34 x 763.2

259.48

Diffuser Length: 0.32 x Lmax

0.32 x 763.2

244.22

Belly Length: 0.08 x Lmax

0.08 x 763.2

61.05

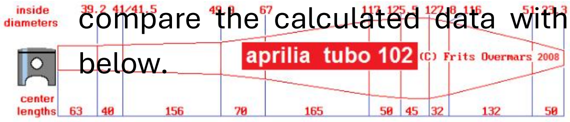
Bufle Length: 0.26 x Lmax

0.26 x 763.2

198.43

Stinger Length : Any Size

The pipe below has a more refined exhaust design and is a true reflection of the real thing. We can compare the calculated data with the data reported below.



14.18 Graham Bell's Formulas

Graham Bell, in his book Two Stroke Tuning and Performance from 1999 gave us excellent insights, formulas, and concepts into how an exhaust actually works. It's because of this wealth of detail that we'll use their research to design our exhausts for everyday use and all types of setups.

Here we will learn how to calculate an exhaust for any engine and for any applicability.

We will learn here:

1. Calculate the adjusted exhaust length L with emphasis on the best engine torque zone;

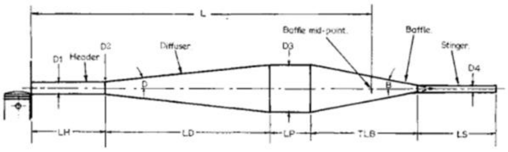
2. Header length LH and diameter D1;

Diffuser length LD, angle D and diameter D2;

4. Length LP and diameter D3 of the belly;

5. TLB length and baffle angle B;

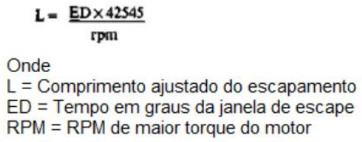
Stinger length LS and diameter D4.



Gaham Bell 's formulas, we will create an exhaust as an example for a hypothetical application of a 50cc racing engine.

Step 1:

The formula below tells us the adjusted length (L) which is the total length of the exhaust to the middle of the deflector cone, which we will learn how to calculate.



$$L = \frac{ED \times 42545}{rpm}$$

Onde
L = Comprimento ajustado do escapamento
ED = Tempo em graus da janela de escape
RPM = RPM de maior torque do motor

To find L, we need to define or measure the exhaust port angle and the engine's highest torque RPM range. Therefore, we'll use a 50cc engine with a 195-degree exhaust angle for racing applications. Therefore, we'll assume the engine operates at 13,000 RPM. Therefore, we'll have:

$$L = \frac{195\ \circ^{\circ}\ 42545}{13000}$$

$$L = \frac{8.296.275}{13000}$$

L = 638mm

It is important to understand that the length L considers the median length of the Baffle, and that this length considers it as if it had length until it actually closes the cone, and not where the stinger begins. Always be careful to use the total length from B to A of the cone and not from C to C1. Figure 4.9 illustrates this.

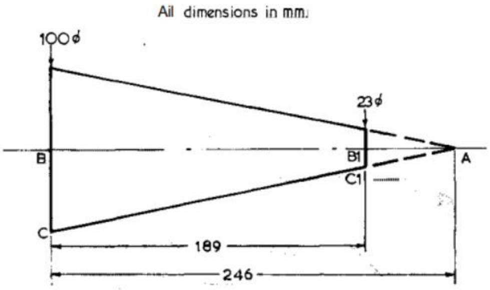


Fig. 4.9 Baffle dimensions.

Step 2:

We first need to find D1, as it will allow us to determine LH and D2. Graham Bell suggests several port diameters depending on displacement in Table 4.2, but D1 is much more closely tied to the existing cylinder port. We can consider the suggested port diameter and add 10 to 15% to D1, or use the existing cylinder port as a starting point for D1. Let's assume the cylinder manufacturer knows the correct size for the exhaust port.

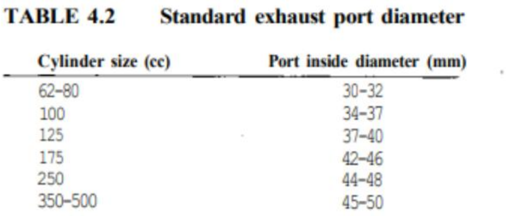


TABLE 4.2 **Standard exhaust port diameter**

Cylinder size (cc)	Port inside diameter (mm)
62–80	30–32
100	34–37
125	37–40
175	42–46
250	44–48
350–500	45–50

Knowing D1, which is the initial diameter of the header, we can calculate its length as shown in Figure 4.1 by multiplying D1 by the suggested value for the desired application. Two numbers are suggested per application, whether racing or motocross/enduro, and if necessary, we should select the one that best fits our final adjusted length.

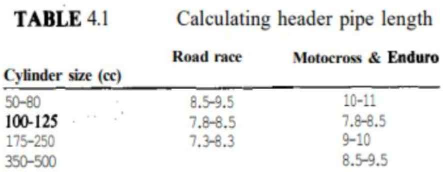


TABLE 4.1 Calculating header pipe length

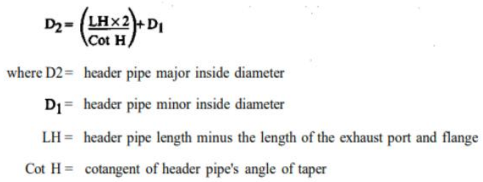
Cylinder size (cc)	Road race	Motocross & Enduro
50–80	8.5–9.5	10–11
100-125	7.8–8.5	7.8–8.5
175–250	7.3–8.3	9–10
350–500		8.5–9.5

Note in table 4.1 that we can choose the multiplier depending on the application we want, racing (high RPM) or motocross and enduro (medium RPM)

Application example for D1 and LH :

In our example, we're developing a 50CC exhaust with a 30mm exhaust port, and we'll assume the cylinder's exhaust port is also 30mm. The application is racing, so we'll multiply 30mm by 8.5, as in the example table, resulting in a header length of 255mm. Therefore, 255 will be our LH.

To determine D2, which would be the final diameter of the header, we need to define the opening angle. There's no consensus on what would be ideal, but it's around 1 to 1.5 degrees. Note in Figure 1 that Bell shows the angle of only one side of the wall of all cones, so the actual opening angle will always be double the calculation. The literature usually refers to the total opening angle of the cones, so be careful. Here, we'll treat the angles as Bell indicated. Therefore, we'll use the following formula:



$$D_2 = \left(\frac{LH \times 2}{\text{Cot } H}\right) + D_1$$

where D2 = header pipe major inside diameter

D_1 = header pipe minor inside diameter

LH = header pipe length minus the length of the exhaust port and flange

Cot H = cotangent of header pipe's angle of taper

Application example for D2:

Still using the previous example, let's consider D1 as 30mm and LH as 255mm. However, we need to discount the measurement from the piston to the cylinder outlet, as this value counts as the LH length, or the cylinder head length. So, let's assume here that the distance from the piston face to the cylinder outlet is 45mm. Thus, we'll consider LH as 255 - 45, adding up to 210mm. We'll use a 1.5-degree cylinder head opening angle, and to do so, we need to look at Table 4.3 for the cotangents of the selected angle and apply them to the formula.

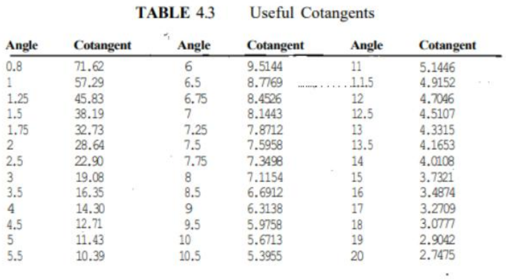


TABLE 4.3 Useful Cotangents

Angle	Cotangent	Angle	Cotangent	Angle	Cotangent
0.8	71.62	6	9.5144	11	5.1446
1	57.29	6.5	8.7769	11.5	4.9152
1.25	45.83	6.75	8.4526	12	4.7046
1.5	38.19	7	8.1443	12.5	4.5107
1.75	32.73	7.25	7.8712	13	4.3315
2	28.64	7.5	7.5958	13.5	4.1653
2.5	22.90	7.75	7.3498	14	4.0108
3	19.08	8	7.1154	15	3.7321
3.5	16.35	8.5	6.6912	16	3.4874
4	14.30	9	6.3138	17	3.2709
4.5	12.71	9.5	5.9758	18	3.0777
5	11.43	10	5.6713	19	2.9042
5.5	10.39	10.5	5.3955	20	2.7475

In this table 4.3, some constants are presented that we will follow depending on the angle we want to use in our exhaust.

$$D2 = \frac{210 \text{ ◌° } 1,5}{38,19} + 30$$

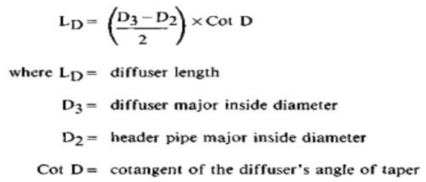
$$D2 = \frac{315}{38,19} + 30$$

D2 = 8.2 + 30

D2 = 38.2

Step 3:

To find LD, we will use the following formula:



$$L_D = \left(\frac{D_3 - D_2}{2}\right) \times \text{Cot } D$$

where L_D = diffuser length

D_3 = diffuser major inside diameter

D_2 = header pipe major inside diameter

Cot D = cotangent of the diffuser's angle of taper

Use the following cotangent depending on the desired application, whether racing or motocross/enduro:

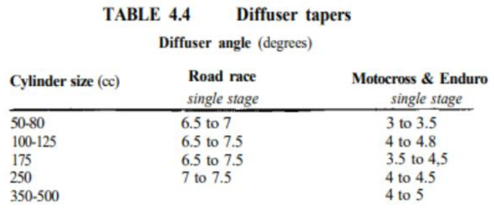


TABLE 4.4 Diffuser tapers

Diffuser angle (degrees)

Cylinder size (cc)	Road race *single stage*	Motocross & Enduro *single stage*
50-80	6.5 to 7	3 to 3.5
100-125	6.5 to 7.5	4 to 4.8
175	6.5 to 7.5	3.5 to 4,5
250	7 to 7.5	4 to 4.5
350-500		4 to 5

Again, here in table 4.4, we can select variables according to the application we want in the diffuser.

But first, we need to figure out D3:

D3 = (2.2 to 2.9) x exhaust port diameter

2.2 for exhausts with less diffuser angle

2.9 for exhausts with a wider diffuser angle

So let's use the constant 2.5

D3 = 2.9 x 30

D3 = 87mm

Knowing D3, we can calculate LD. First, we need to define the diffuser angle, as shown in Table 4.4. Let's choose an angle of 6.5 degrees. The cotangent value for 6.5 degrees is found in Table 4.3 and corresponds to 8.77.

$$\text{LD} = \left(\frac{D3-D2}{2}\right) \text{ x Cot D}$$

$$\text{LD} = \left(\frac{87-38{,}2}{2}\right) \text{ x } 8.77$$

LD = (24.4) x 8.77

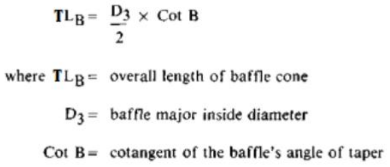
LD = 214mm

Step 4:

When we defined D3, we already found the belly diameter. The belly length (LP) depends on the deflector cone, so we get the adjusted length within the expected range. We'll calculate LP again after calculating the deflector cone.

Step 5:

To find the TLB length, we will use the following formula and the angle values according to table 4.6. For our example, we will use the Buffer angle of 12 and find the cotangent in table 4.3.



$$TL_B = \frac{D_3}{2} \times \text{Cot B}$$

where TL_B = overall length of baffle cone

D_3 = baffle major inside diameter

Cot B = cotangent of the baffle's angle of taper

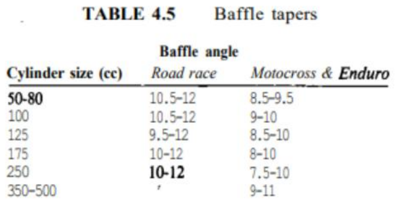


TABLE 4.5 Baffle tapers

Cylinder size (cc)	Baffle angle *Road race*	*Motocross & **Enduro***
50-80	10.5-12	8.5-9.5
100	10.5-12	9-10
125	9.5-12	8.5-10
175	10-12	8-10
250	**10-12**	7.5-10
350-500		9-11

In table 4.5 we can select the variable for baffle calculation.

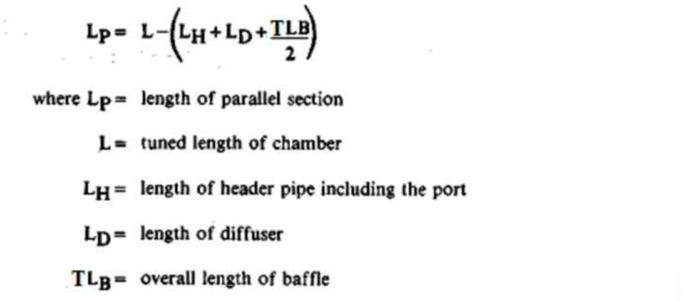
—

TLB = $\left(\frac{87}{2}\right)$ x Cot B

TLB = (43.5) x 4.7

TLB = 204mm

Now we can find the belly length LP with the following formula:



$$L_P = L - \left(L_H + L_D + \frac{TLB}{2}\right)$$

where L_P = length of parallel section

L = tuned length of chamber

L_H = length of header pipe including the port

L_D = length of diffuser

TL_B = overall length of baffle

LP = L - (LH $+ LD + \frac{TLB}{2}$)

LP = 638 - (255 $+ 133 + \frac{204}{2}$)

LP = 638 - (255 + 214 + 102)

LP = 638 - (571)

LP = 67mm

Step 6:

Finally, we'll define the stinger using Table 4.6. However, always start testing with the largest diameter and shortest length. Getting the stinger wrong can cause overheating and breakage.

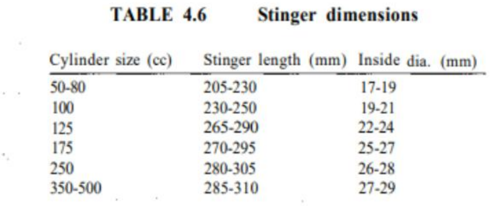


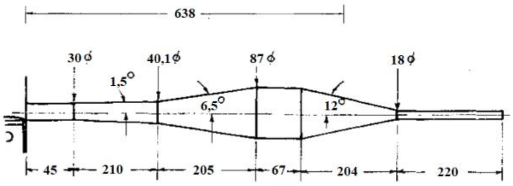
TABLE 4.6 Stinger dimensions

Cylinder size (cc)	Stinger length (mm)	Inside dia. (mm)
50-80	205-230	17-19
100	230-250	19-21
125	265-290	22-24
175	270-295	25-27
250	280-305	26-28
350-500	285-310	27-29

In table 4.6 we can directly select the length and diameter of the stinger according to the engine displacement.

For our example, we will use a stinger measuring 18mm in diameter by 220mm in length.

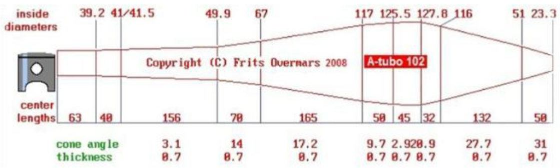
Once our exhaust example is finished, it will have the following dimensions:



ESCAPAMENTO PARA 50cc
JANELA DE ESCAPE: 195°
RPM ALVO: 13.000
APLICAÇÃO: CORRIDA

14.19 Case studies

Aprilia GP RSA 125 Exhaust



Let's take a look at some exhausts and try to understand their construction versus application. Let's start with the RSA exhaust.

By my calculations, the header had 3.1 degrees of progression. This progression isn't much different from any other performance-oriented exhaust. The header is 259mm long.

I calculated the diffuser's opening angle and found it to be 17.2 degrees, which is quite a lot. This tells us that the exhaust used had a strong tendency to create a strong, concentrated vacuum wave, seeking maximum intake of the crankcase mixture. Note here that the diffuser's construction strategy was used to aid peak power at a very high RPM. This is important to consider since this engine was constantly operating at high RPMs. The diffuser is 285 mm long.

The belly was short and had a diameter of approximately 127 mm, a large diameter created by the diffuser's wide opening angle. The belly's length is 45 mm.

The baffle was 27.7 degrees wide and 214mm long. This tells us that the angle was wide, seeking concentrated return waves.

The Stinger is of the baffle end restricted type and was 23.3mm.

The conclusion we have is that a tube was developed to concentrate the waves in all directions and benefit the peak power for an engine that has a single objective, which is to win a closed circuit race.

Gemoto RD135 Exhaust

Let's analyze a well-known exhaust which is the Gemoto for RD135.

The header has a 1.8-degree slope. This angle is common in everyday exhausts and light tunes. The length is 280 mm, plus 60 mm of internal cylinder head and flange on the RD135.

I calculated the diffuser's opening angle and found it to be 11.8 degrees, which is common in exhausts designed to spread the powerband of street-legal engines. Note that the diffuser's construction strategy was designed to enhance midrange power, neither spreading it too much nor creating peaks. The diffuser's total length is 260 mm.

The belly is 90mm long, which is long and common in this type of application, and has a diameter of 105mm, created due to the diffuser's opening angle and length.

The baffle has a 22.9-degree aperture and a length of 200mm. The angle is small, aiming to spread the shock wave and also the power curve.

The Gemoto 's stinger is 19mm internal and 76mm long. The silencer is 22mm internal and 145mm long.

The ratio is 340, 260 and 290mm (38%, 29% and 32%) and the adjusted length is 790mm.

The conclusion we reach is that this tube was developed with everyday applications in mind, aiming for lightweight performance while maintaining a balanced power curve for comfortable use. Its length is long, designed to suit stock engines with low-RPM torque.

Gianelli Exhaust

Let's analyze an imported Italian exhaust from the Giannelli brand for 50/70cc.

The header has a 1.99-degree angle. This angle is common in exhausts for everyday use and light- to medium-duty setups. The length is 240 mm plus 60 mm of the cylinder head, including the yoke.

The diffuser angle is 13.4 degrees, which is a greater angle, given that the exhaust is used on an engine with a CVT transmission. Note here that the diffuser's construction strategy was used to concentrate the vacuum wave as much as the design allows. The diffuser's total length is 230 mm.

The belly is short at 50mm long and has a diameter of 95mm, created due to the diffuser's opening angle and length.

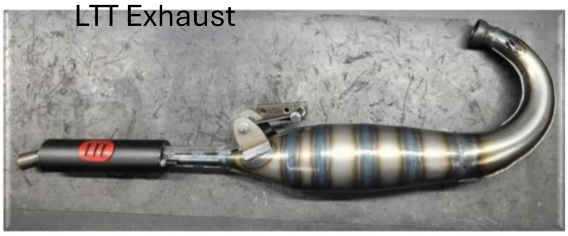
The baffle has a 21.7-degree opening and a length of 180 mm. The angle is small for this application, but it aims to spread the shock wave and also the power curve.

The stinger has a 16mm internal bore and is 100mm long. The silencer has a 22mm internal bore and is 200mm long.

The proportion between the parts is 300, 230 and 230mm (39, 30 and 30%). The adjusted length is 670mm.

The conclusion we have is that this tube was developed for racing applications , seeking performance, but with a conservative cuff . It's certainly designed to facilitate CVT tuning, as it helps spread the powerband. Its length is quite short, making it suitable for engines running at very high RPMs.

LTT Exhaust



Let's analyze the exhaust that broke the record in 2020 with 8.6s at 143km/h in 201 m. Recommended for 80 to 100cc engines.

The header has a 2.63-degree rake. This angle is more open and is used in heavier preparations. The length is 240 mm plus 60 mm of the inner cylinder, including the acorn.

The diffuser angle is 12.7 degrees, which is relatively steep and well-suited to an engine with a CVT transmission. The overall diffuser length is 220 mm.

The belly is short at 65mm long and with a diameter of 98mm, created due to the diffuser's opening angle and length.

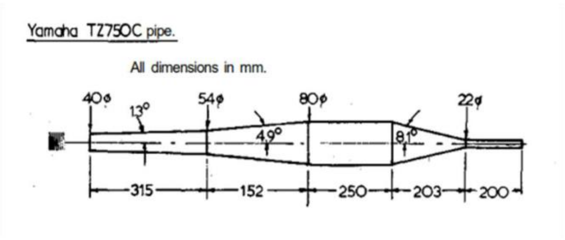
The baffle has a 27-degree opening and a length of 155 mm. The angle is quite high and the length is short, seeking to concentrate the shock wave and the power curve in a very narrow band.

The stinger has a 19mm internal bore and is 100mm long. The silencer has a 22mm internal bore and is 250mm long.

The proportion between the parts is 300, 220 and 220 (40, 29 and 29%). The adjusted length is 665mm.

The conclusion we have is that the pipe concentrates the powerband, seeking maximum power in a narrow band. The length is quite short, tuning any engine at very high RPMs, delivering plenty of power.

TZ750 Exhaust



Let's now analyze the exhaust of a 750cc Yamaha racing motorcycle. It had four cylinders, and each exhaust worked with 187.5cc.

The header has a 2.60-degree progression. This angle is more open and is used in heavy preparations. The length is 315 mm.

The diffuser angle is only 9.8 degrees, which is a shallow angle and aims to spread the vacuum wave. The total length of the diffuser is 152 mm.

The belly is extremely long, at 250mm long and only 80mm in diameter, created by the diffuser's low opening angle and short length. The belly is long because the strategy here was to increase the adjusted length, and it is at the belly that length is added or removed.

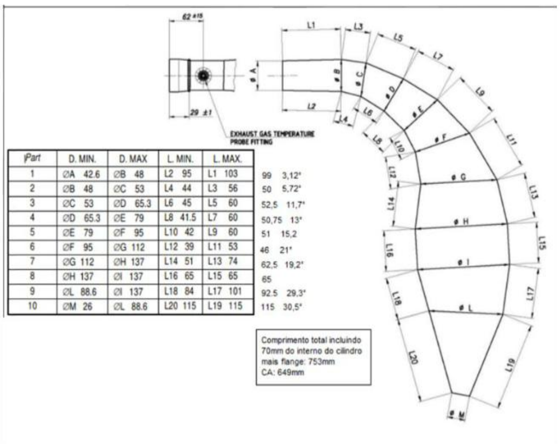
The baffle has only 16.2 degrees of aperture and a length of 203mm. The angle is quite low, and along with the length, it aims to extend the power band.

The stinger is 22mm internal and 200mm long.

The aspect ratio between the parts is 315, 152 and 453mm (34, 16.5 and 49%). The adjusted length is 819mm.

The conclusion we have is that the pipe seeks to spread the powerband as much as possible. The length is quite long, bringing the torque band down to low RPMs. Since the engine has a lot of power, and concentrating it in a narrow band could lift the front end or even lose traction, the strategy was to spread this power across a wider powerband, avoiding constant gear changes.

X30 SS Exhaust



Part	D. MIN.	D. MAX	L. MIN.	L. MAX.		
1	∅A 42.6	∅B 48	L2 95	L1 103	99	3,12°
2	∅B 48	∅C 53	L4 44	L3 56	50	5,72°
3	∅C 53	∅D 65.3	L6 45	L5 60	52,5	11,7°
4	∅D 65.3	∅E 79	L8 41.5	L7 60	50,75	13°
5	∅E 79	∅F 95	L10 42	L9 60	51	15,2
6	∅F 95	∅G 112	L12 39	L11 53	46	21°
7	∅G 112	∅H 137	L14 51	L13 74	62,5	19,2°
8	∅H 137	∅I 137	L16 65	L15 65	65	
9	∅L 88.6	∅I 137	L18 84	L17 101	92.5	29,3°
10	∅M 26	∅L 88.6	L20 115	L19 115	115	30,5°

Comprimento total incluindo
70mm do interno do cilindro
mais flange: 753mm
CA: 649mm

Let's analyze the exhaust of a kart engine with a Shifter gearbox from the Iame brand called X30 SS.

The header initially has a 3.12-degree angle and then a 5.72-degree angle of progression. This is a very wide angle and is used in heavy-duty setups. The length is 219 mm, considering the 70 mm I estimated between the cylinder bore and the flange.

The diffuser is formed by several angles of 11.7, 13, 15.2, 21, and 19.2 degrees. According to Graham Bell, this progression of various diffuser angles allows it to be shorter. However, it forms a rather large final angle, creating a narrow and very strong vacuum wave. The total length of the diffuser is 262 mm. It's even difficult to tell where the header ends and the diffuser begins.

The belly is short, measuring 65mm long and 137mm in diameter, created due to the diffuser's wide opening angle. The belly is short with the strategy of creating a short exhaust for high RPM operation.

The baffle has an absurd 30-degree opening and a length of 207 mm. The angle is quite high and seeks to create a narrow, strong return pulse.

The Stinger uses the FOS style and has a 26mm internal bore, with no length. The silencer has a 48mm internal diameter and is 410mm long.

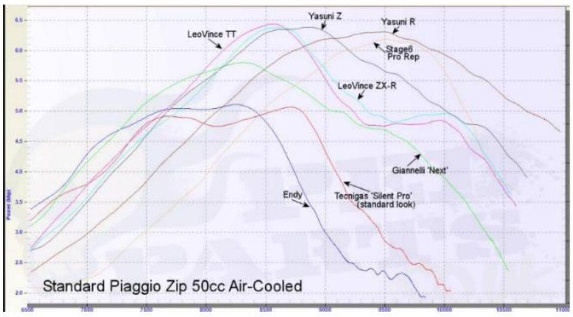
The proportion between the parts is 219, 262 and 272mm (29, 35 and 36%). The adjusted length is 649mm.

The conclusion we have is that the pipe seeks to concentrate the powerband as much as possible. The length is quite short, tuning the engine to a very high RPM. Because the engine has a lot of power in a narrow power band, the gearbox is quite demanding, and this is what we notice in this category of karts, which have very close gear changes. Always trying to work within the narrow range in which the engine operates.

14.20 Exercise

Now that you've reached this point, I want you to do the exercise of observing each exhaust and trying to guess what power curve it delivers. Try comparing the power curve with the corresponding exhaust and, by observing its geometry, understand why it delivers this behavior.

Corresponding power curves



Chapter 15 – Crankshaft

15.1 Introduction

The crankshaft's function is to transmit the energy created by the combustion chamber through the piston and transform it into motion. This energy is then transmitted through the crankshaft to the gears or belts, all the way to the wheel itself.

The quality of the crankshaft's moving assembly, which consists of pins and bearings, including the connecting rod, is vital to the engine's longevity and reliability. That's why we need to assess the health of this assembly and ensure its integrity before considering any modifications. Whenever possible, opt for original connecting rods and bearings or those from renowned brands in the manufacture of performance