Exhaust port with boosters after final preparation. This 135cc cylinder produced over 40 hp at the wheel. The stock cylinder produces 17 hp according to Yamaha.

Chapter 8 – Cylinder: Transfer Window

8.1 Introduction

First of all, we need to familiarize ourselves with the nomenclature of transfer windows that the literature deals with.

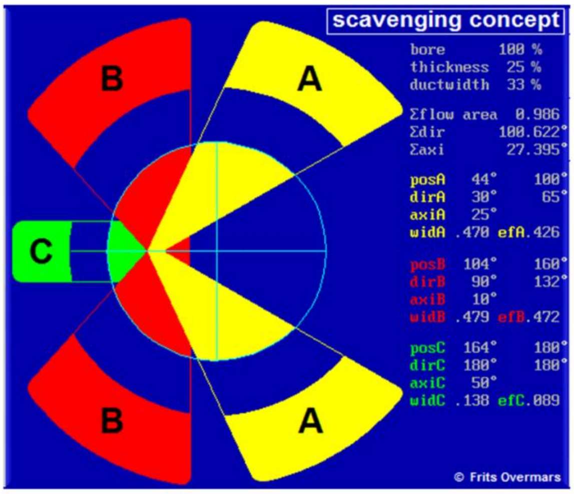
We name the windows with letters and those closest to the escape window start with the letter A and continue with the letters B, C and D as they move away.

The number of transfer ports depends on the cylinder construction and its application. When the cylinder is designed for use in everyday engines that don't require performance, it will typically have few ports. The opposite also applies when many ports are used for performance applications.

8.2 Angles

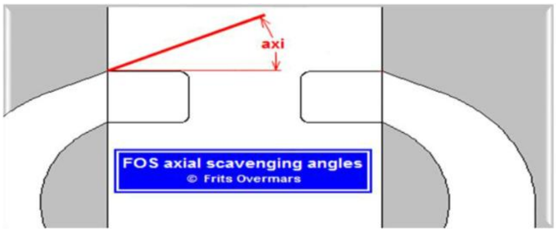
According to Fritz Overmars, the transfer angles should follow the pattern shown below. Modern cylinders follow this orientation pattern. However, we must understand that older cylinders do not, and that trying to modify this orientation can be difficult. In certain cases, it's best not to change it, as there's a risk of further damaging the flow unless we know what we're doing and have the appropriate tools. What we can see is that the transfers are directed to the same position, which would be the rear half of the cylinder. Directing the transfers to this position prevents mixture loss to the exhaust.

Below we are seeing the flow positioning as if we were looking at the cylinder from the top.



Notice that the blue circle is the cylinder diameter, and that at the intersection of the transfers, there's a space that serves as a divider between the transfers, preventing the ring from falling into them. We see this in transfers A to B and B to C. We notice that here we have the maximum open area possible to increase feed flow. Typically, these dividers are 2 mm wide. The transfer positions are indicated in the table below as posA, posB, and posC, referenced by angles relative to the center of the exhaust port. The orientation is indicated as dirA, dirB, and dirC, showing the orientation relative to the circumference.

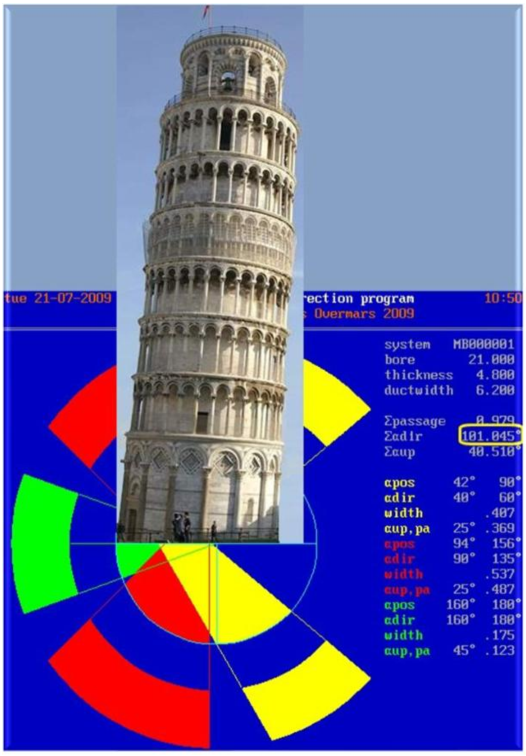
Another important piece of information is the axial angle, which is the angle the jet will have in relation to the piston, as shown in the image below. This angle is described as axiA, axiB, and axiC. According to FOS, transfer A should be oriented at 25 degrees, transfer B at 10 degrees, and transfer C at 50 degrees.



8.3 The Tower of Pisa

If you research the literature on the best direction for your transfers, you'll come across Fritz's Leaning Tower of Pisa theory. The theory states that the resulting flow from the transfers should meet at the rear of the cylinder and rise at an angle of approximately 100 degrees toward the cylinder head. And that the flow should not curve and end up at the exhaust port. What prevents this from happening is the axial angle of the main ports A, pointing slightly upward, suggesting that the tower should be held by the top rather than the base, as shown in the image below.

Flow being held from above so that it does not bend too early and exit through the escape window.



8.4 Cleaning the cylinder

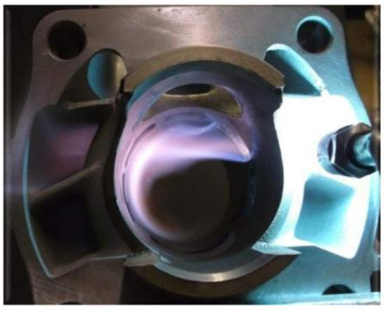
Transfer valves have two basic functions. The first is to sweep away the combustion gases from the last combustion cycle. We want to achieve cylinder scavenging, which is simply expelling the combustion gases from the cylinder through the exhaust port and renewing its atmosphere with a fresh air/fuel mixture. The hot gases from the last combustion cycle lack oxygen and are not suitable for the next combustion cycle, so they must be swept away as much as possible.

Professor Polati (an engineer who worked on Formula 1) said that the hot gases have such a large temperature difference compared to the fresh mixture that the two don't mix—that is, there's a thermal barrier between them. However, this is true as long as there's as little turbulence as possible, which prevents the gases from stirring and actually mixing. We'll see how to avoid this turbulence later.

According to Gordon Jennings, most two-stroke engines have a volumetric efficiency of 80%. In other words, if the engine has 100cc, it can admit around 80cc of fresh mixture. This means that 20% of the cylinder's atmosphere is not renewed. Considering this, imagine that of this 80% of fresh mixture, some of it may have mixed with the burned gases, and this volumetric efficiency could be even lower. Avoiding turbulence within the cylinder is part of the quest for power.

8.5 Turbulence

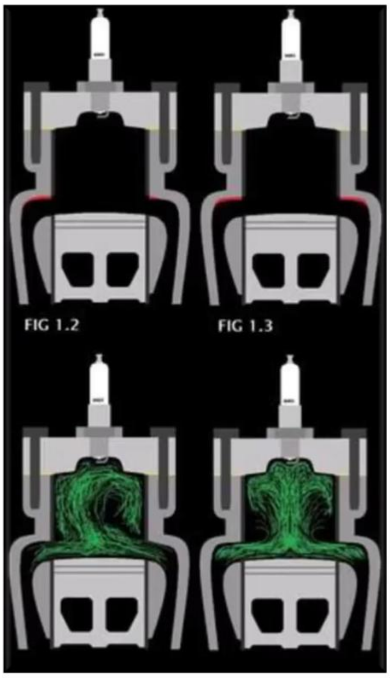
We can name three things that cause turbulence within the cylinder. The first is different heights in opposite transfers. In other words, windows with different heights from one side to the other. This creates a swirl within the cylinder instead of collision between the flows, which slows down and causes the mixture to rise. Below, we can see what happens when one side opens before the other, causing rotation and unwanted turbulence. The equal height of the windows causes collision and slows down the flow, calming the mixture and directing it upward.



The second cause of turbulence is the opening of small transfers before larger ones. This results in very high velocity due to the high pressure concentrated in transfers with small areas.

Preferably, we should open the larger transfers to calm the flow. This is called opening staggering, as we'll see in the next slide. This is a big- bore cylinder I made with the opening starting with transfers A and followed by B and C. There's no standard pattern in the staggering, as some cylinders open B first, others C, and others open all at the same time. What should be considered is the transfer size and the Leaning Tower of Pisa theory.

The third cause is different window sizes from one side to the other, causing stronger flows in one direction, which results in eddies inside the cylinder.



In the cylinder below, ports B and C were directed at a fairly high axial angle. Therefore, the velocity they would reach the cylinder head would be very fast. In this case, I opened ports A, which had a 22-degree angle, then ports B and C, both at 40 degrees.

If ports B or C opened first, there would be too much velocity, and the flow would reach the cylinder head much earlier than the flow from ports A. It's possible that the mixture would end up in the exhaust, in addition to agitating the cylinder atmosphere excessively, resulting in the new flow mixing with the burnt gases.

What I tried to do here was think of the Leaning Tower of Pisa, opening A blocks first and then B and C, trying to hold back the flow and arriving at the same time. Of course, it's very difficult to estimate the times, but this is how we can get close to what would be ideal.

8.6 How to measure

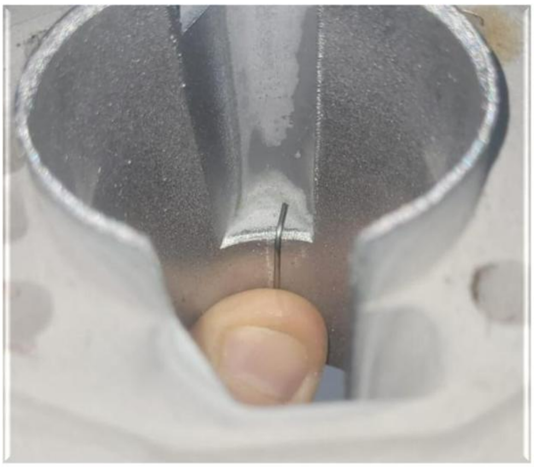
We can measure the axial angulation of the transfers using our graduated disc and with the help of a 1mm thick piece of tin.

Tin is soft and has no elastic properties, meaning it doesn't return to its original position after bending. This allows us to easily shape it and extract the axial curvature of the transfer. Understanding these angles is important for defining the desired strategy. We'll discuss angulation and its causes later.

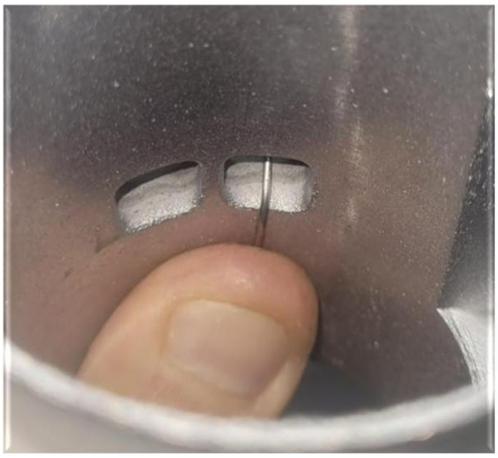
Next, we'll extract the axial angle of the transfers from a Rocati cylinder. This method can be applied to any cylinder.

Here, we'll measure the angle of window A. Using the tin, we'll bend the tip to the same angle as the window's exit. Now, we'll align the bottom of the tin at 180 degrees, and our reference point will be 90 degrees. Using a ruler, check which way the tip of the tin is pointing. Here, I've created an imaginary red line. In this case, the tip is pointing at 70 degrees. Therefore, from 70 to 90 degrees, there's a difference of 20 degrees. This is the angle of transfer A, as shown below.

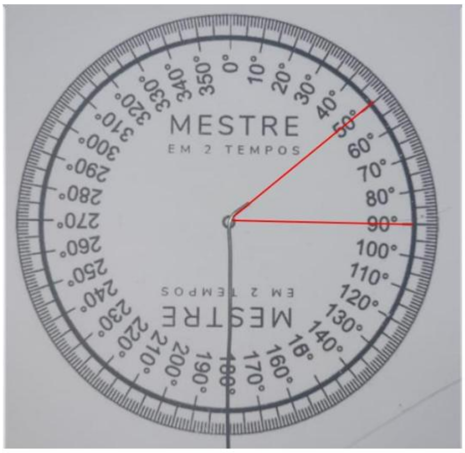
Now let's measure the angle of the B windows, which in this case are the rear ones. Here we have a difference of 40 degrees. This is the angle of transfer B. We'll typically see greater angle in the rear transfers, since they're opposite the exhaust port, and pointing upward is the best option.



Placing the tin on the graduated disc, we will have an axial height of 20 degrees.



Placing the tin on the graduated disc, we will have a height of 40 degrees.



8.7 Case studies

Doppler brand 50cc AV-10 cylinder with windows A, B and C. I measured their angle and found: A 15 degrees, B 0 degrees and C 40 degrees.

Note the construction of the windows, which were very well thought out and well built, as the piston's small diameter allowed for transfers with perfect tapering and direction.

Here we have an 82cc AV-10 cylinder from Parmakit. Also with ports A, B, and C. I measured their angles and found: A 25 degrees, B 5 degrees, and C 40 degrees.

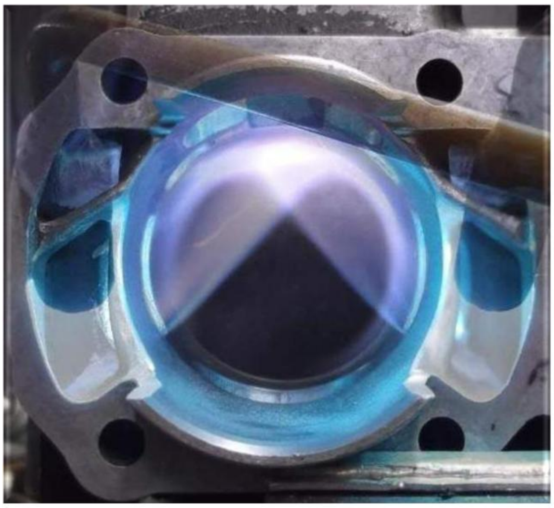
Here, we don't have as much space for transfers, as the piston is 50mm long, and the port design had to be adapted to the existing space. This explains why smaller displacement cylinders generate more HP per cubic capacity, as the transfer ports are better constructed.

8.8 Targeting

Two-stroke cylinders have a geometry that prevents perfect fuel delivery, which would involve having transfer ports all around the circumference, pointing in the same direction and canceling each other out, creating a single upward flow. Unfortunately, this isn't possible because the exhaust port is on one side.

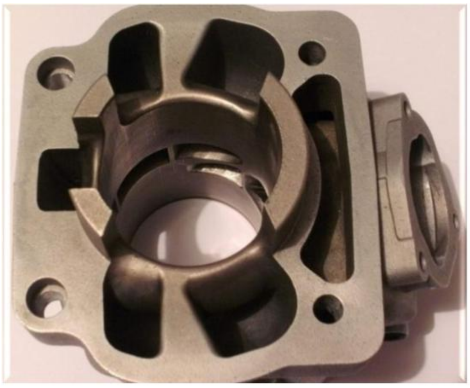
So, the best we can do is direct the flows backwards and prevent them from ending up inside the escape window.

We must avoid creating eddies within the cylinder, avoiding uneven heights and sizes. This creates stronger flows or flows in different directions from one side to the other. The idea here is for the flows to cancel each other out and slow down.



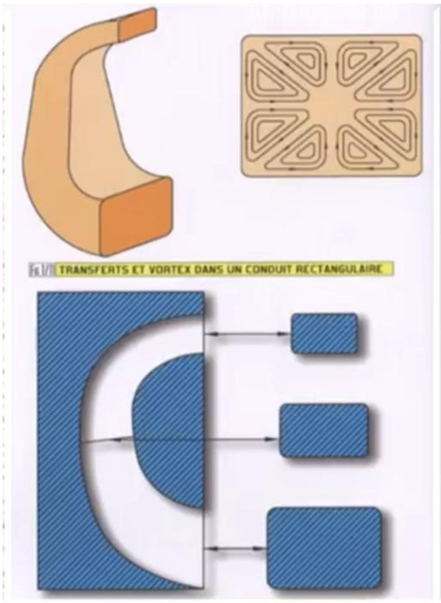
The axial angle tells us how fast the flow will reach the top of the cylinder. The greater the angle (the more upward it is), the faster it will collide with the cylinder head, curve, and possibly exit through the exhaust port. And the smaller the angle, the greater the chance of this flow colliding with the flow on the opposite side, slowing it down, and preventing it from rising so quickly that it curves and exits through the exhaust port. Considering the flow velocity, we can understand that smaller angles will yield better results at lower RPMs, and larger angles will benefit higher RPMs. This idea helps us adapt the transfer angle to the application we need.

Once again, I emphasize that without more in-depth knowledge and proper tools, it's best to leave them alone. Removing burrs and machining defects is sometimes enough.

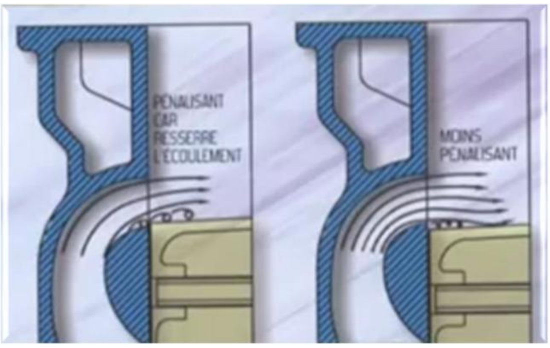


8.9 Design

The best transfer valve design will always be one that tapers from the cylinder inlet to the outlet. This shape improves flow and accelerates the mixing process. The faster the mixture moves, the greater the charge we can inject into the cylinder due to the short period the transfer valve is open. It's important to understand that not all cylinders come with this design from the factory, but it's important to note that it's the best design available.



The transfer outlet must be fluid with the piston, which must be neither above nor below, avoiding turbulence.



The first difference to note is the size of the inlet of transfer port A and B relative to the size of the port window where the charge exits into the cylinder.

Honda and Kawasaki use the old, widely used idea of forcing cargo through a narrow duct to increase speed.

The output port is half the size of the input port. The Metrakit, however, shrinks the size by about 15 to 20 percent by focusing on the principle of "mass transport" rather than velocity.

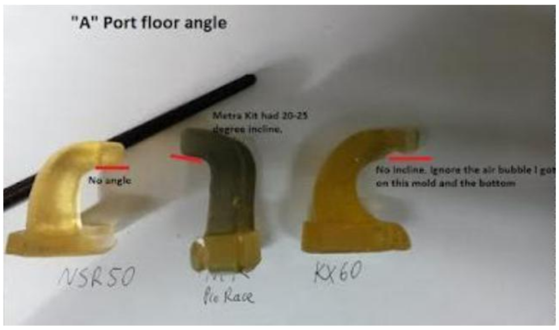
Now let's look at the inner radius of the transfer ducts. Kawasaki has the ideal design with the largest radius available.

The MK and Honda have suboptimal shapes, especially the MK. It's possible these two cylinders are limited by space constraints.

Curved transfer designs are the ones that will have the best efficiency before and after the engine's best torque zone.

Of the three transfers presented, Kawasaki's is the most modern.

Metrakit cylinder and its transfer port A were the only ones to have any upward axial angle. This is done to affect the central column of fresh charge, holding it higher to prevent it from flowing out the exhaust port, according to Friz's Leaning Tower of Pisa theory. Honda and Kawasaki cylinders have no axial angle. Care must be taken with right angles when using rounded-head pistons, as it will act as a ramp and direct the mixture in an unknown direction.

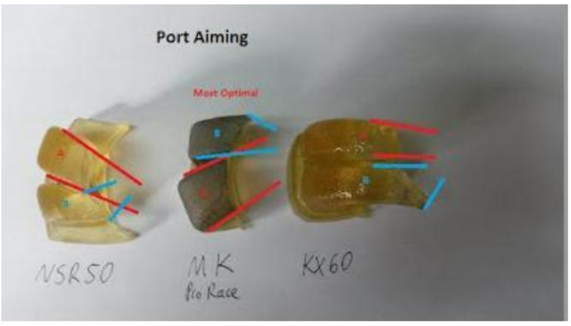


And finally, we see the flow direction as it exits the transfer case. The MK is the closest to the RSA cylinder angles and Fritz's suggestion.

The NSR crosses the flows, trying to neutralize them into a single one, colliding with the opposite side and climbing. The KX, on the other hand, seems more risky, with the A flows slightly directed backward and the

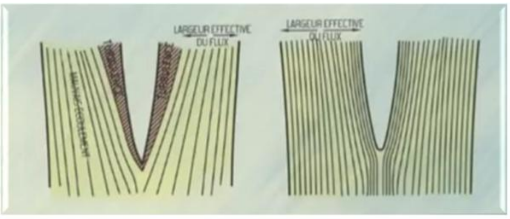
B flows pointing forward. You'd think this has been tested and certainly works, but we don't want to take that risk.

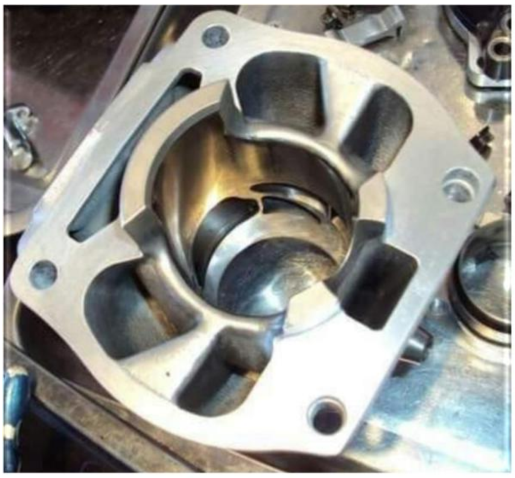
It's interesting to see that some manufacturers followed the RSA idea and also to realize that others never did.



One of the biggest taboos in tuning is the divider between the A and B windows, where some tuners sharpen it in an attempt to improve the mixture's upward flow. The biggest proof that refutes this idea is the Aprilia RSA. The divider isn't even rounded.

Just as the front of an airplane wing is not sharp, we have so many other rounded designs that demonstrate that sharpening is not the best solution, as shown in the photo below.





8.10 Case studies

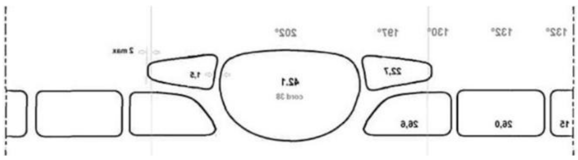
Below, we can see the external layout of the Aprilia RSA cylinder. Note the transfer design, curvature, and direction.

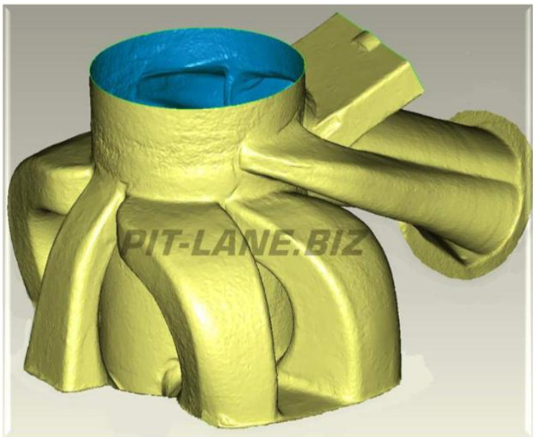
We can see that window A points backward with a slight upward axial angle and the taper from inlet to outlet. Also note its inward curvature.

Transfer B also has a highly arched internal curvature and a lower, almost flat axial angle. The direction is lateral and has a forward angle just at the exit. The resulting vector should point toward the rear half of the cylinder, which is the position indicated by Fritz. The height appears to be higher than that of transfer B, since it is larger.

Transfer C points upwards to avoid throwing mixture into the exhaust.

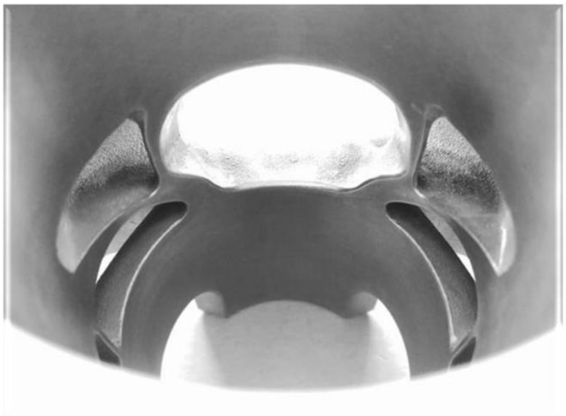
The graduation used in the transfers was 132 degrees in windows B and C and 130 degrees in windows A. If the best cylinder ever built uses this graduation, this is an excellent starting point for us preparers.





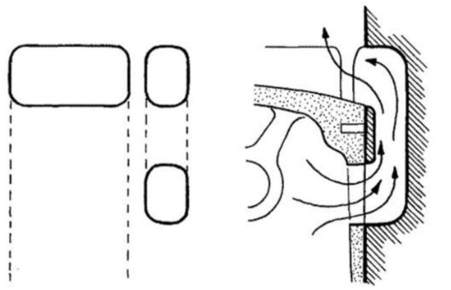
Below, we can see how far the A ports protrude forward and how modern cylinders have arched the front of the transfer ports to make room for the exhaust port boosters. The intention is to have maximum transfer area, competing for space with maximum blowdown area.

Note the divide between windows A and B; they're as thin as possible, always seeking maximum transfer area. You can also see that we have very small radii. Here, we can have practically square and flat windows, since their width is small and we don't run the risk of jamming the rings.



8.11 Blind windows

Some cylinders already come with blind ports, and others we can add to them. Blind ports allow for more flow into the cylinder, increasing the transfer area and, consequently, more air/fuel mixture within the combustion chamber. The great advantage of this type of port is its ease of construction and the ability to allow mixture to flow inside the piston, increasing its cooling and better lubrication of the upper cage. The port is nothing more than a slot in the cylinder and a hole in the piston, which feeds this channel and flows upward, carrying mixture into the cylinder.

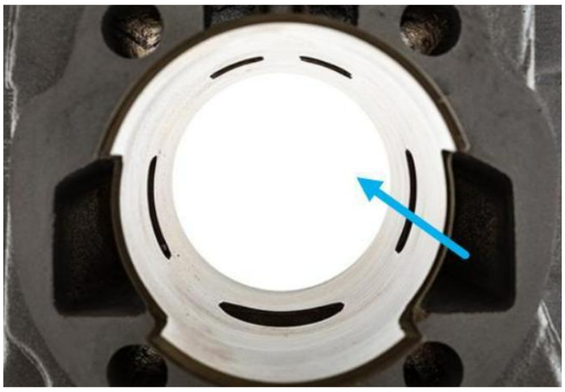


Boost ports fed from holes high in the piston skirt cool and oil the piston crown and wrist pin, while improving power output.

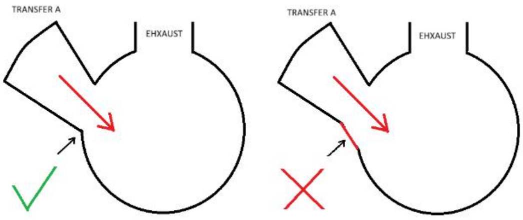
8.12 Inertia

We need to understand that the flow has inertia and, like a bullet fired from a gun, it doesn't want to deviate from its trajectory. If we create a direction from the rise to the exit of the window, this flow tends to follow that same direction. This is why changing only the exit to the cylinder doesn't change the flow or increase the size of the window. On the contrary, as we saw before, the window should gradually reduce its area as it rises through the cylinder. As I always say, reflection and conviction are necessary whenever we pick up the grinder. Thinking carefully before changing the transfers is no exception.

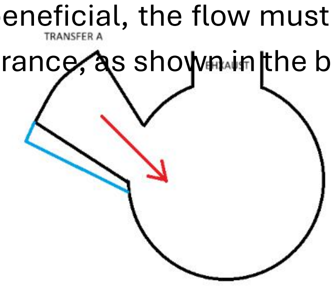
Be wary of recipes offered for free in online videos. Most of them have never been tested. The image below on the right illustrates the error exactly.



Not only does the window outlet become larger than the middle of the duct, losing the aforementioned progression and slowing down the mixing, but it also prevents the flow from moving backward, as the flow's inertia prevents it from changing direction. Therefore, this type of preparation is useless.

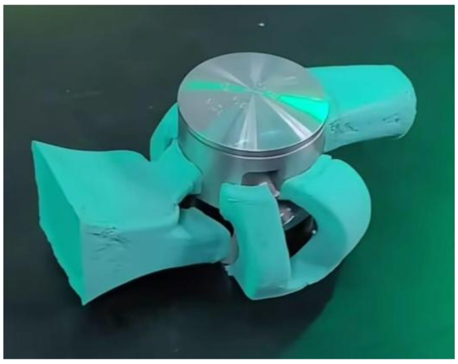


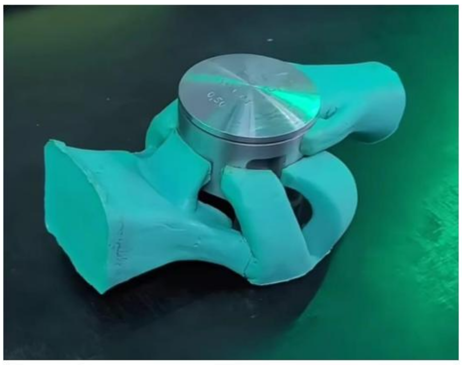
If the aim is to increase the transfer area, which is very beneficial, the flow must be corrected from the duct entrance, as shown in the blue line below.



Examples of transfer duct preparation starting from the original model with work both at the transfer outlet to increase the area, and from the duct inlet:

Below we can see the increase in clipboard in windows A, B and C.





8.13 Graduation

Graham Bell suggested several ratings as a reference point when considering an engine's applicability. Of course, he suggests a reference point here, but it already shows us how the transfer window rating affects the RPM at which the engine will deliver power.

After everything discussed so far, we understand that the design and axial angles are quite difficult to work with. That's why preparation will usually begin with the desired transfer height.

I usually use flanges and gaskets under the cylinder to find the graduation I want for them and then mark the graduation I want on the exhaust port, which is infinitely easier to work with, since it has access through the exhaust port and allows external access with a straight grinder.

TABLE 3.2 Transfer Port duration

RPM	Transfer duration (°)
6,500	120-124
8,000	124-128
9,000	126-130
10,000	128-132
11,000	130-134
12,000	132-136
13,000	134-140
14,000	136-142

8.14 Modeling

The first time I tried to tinker with transfer systems, and I made a huge mistake, was when I built an RD135 engine. Besides increasing the stroke, I also increased the crankshaft stroke. This meant I had to raise and lower the transfer height, removing material from the top and bottom. I used a 125cc Y1 cylinder, which has a lower stroke than the Y3 and Y4 cylinders. Therefore, I opened only the duct outlet, leaving the middle as it was. This way, the transfer flow was limited to the central area, and when the flow passed through the outlet, it encountered a larger area, slowing it down. The result was that this cylinder disappointed me because it didn't deliver the expected power. If I remember correctly, this engine didn't exceed 32 hp at the wheel. Luckily, a friend sent me some rubber or silicone to test, which reminds me a lot of the material used in artificial baits. It can be melted with heat and inserted into the transfer ducts to model and monitor the transfer process from inlet to outlet. After that, I never stopped doing this process, and today I use a silicone that hardens with a catalyst. It's more practical because it doesn't require heat. This material is used by dentists as dental molds. The only thing to be careful about is that you must coat the ducts with petroleum jelly or silicone mold release agent to prevent them from sticking. I've forgotten to do this, and the silicone stuck to the entire length of the duct. It took me hours to remove it using a grinder and abrasive stone.

You will easily find this type of silicone for molds.

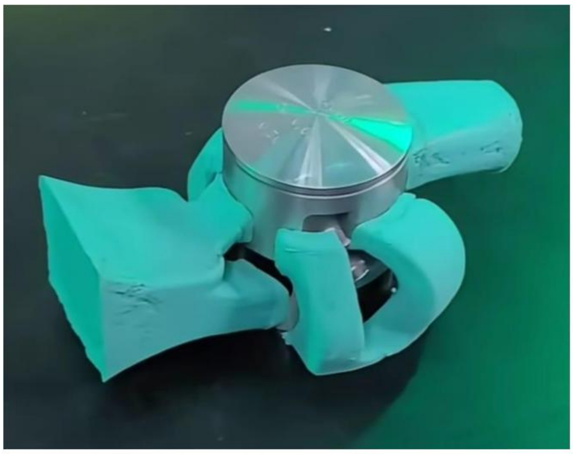
8.15 Clipboard

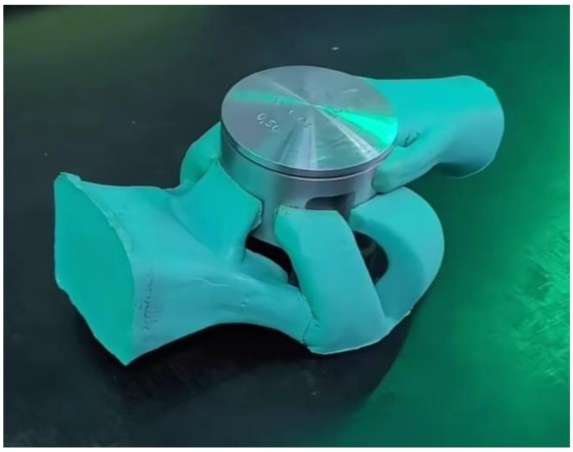
This is one of the best ways to gain power, as increasing the transfer area ensures more power to the engine. However, this technique needs to be carefully considered to ensure it doesn't deviate from the chosen design scaling, lose proper routing, or end up with an irregular duct, which would disrupt the progressive area reduction from inlet to outlet. If you can increase the transfer area while maintaining these two precautions, you'll gain power. Example of an increase in the duct size in the B port of a DT180 cylinder, which achieved over 50 hp at the wheel.

8.16 Boyesen ports

The Boyesen Ports connect the cylinder's intake port to the auxiliary transfer ports, benefiting intake flow, since at certain times the piston passes through the main center port and can disrupt flow. This is another taboo among tuners. Some say there's no benefit, but looking at Banshee cylinders and other racing cylinders, we see they are present. Cylinders, like other cylinders, can have these ports open. Of course, drilling 8mm holes won't help, so it's necessary to reinforce the cylinder with welding and open it in a way that truly improves flow.

Below, a cylinder that didn't have Boyesen ports and how it looked after its addition.





8.17 Admission

In my experience, the intake is always oversized, meaning they sometimes needlessly move it. The biggest problem with opening the intake is that it reduces the contact area of the crossbar that divides the two intake ports. If this crossbar is too narrow, the piston ends up touching it, as the oil film can't separate the two. For light and medium builds, there's no need to work there. Instead, add Boyesen. ports to supply flow in cases of heavy tuning. I did a test by lining a DT180 cylinder and keeping the intake completely stock, narrowing the crossbar and without raising or lowering the two oblong bores. I added two generous Boyesen ports, and this cylinder was able to exceed 50 wheel horsepower.

Exaggerated narrowing of admission

Many times, the cylinder has no preparation, which is the case with this cylinder, and the intake is not and has never been the bottleneck of the engine. We also see boyesen useless ports there. Compare the narrow passage of the reed tap with the original intake port, you will see that they will not cause restriction.

Below is the intake of the DT180 cylinder I mentioned earlier.

Make sure the divider is wide enough to maintain a sufficient oil film to prevent friction between it and the piston. I compensated with Boyesen ports of a very reasonable size to compensate for the original size intake.

Chapter 9 – Cylinder: Blowndown

9.1 Introduction

Blowdown is an engine parameter little known to tuners and often mistakenly ignored. This is because the literature rarely addresses the subject, and when it