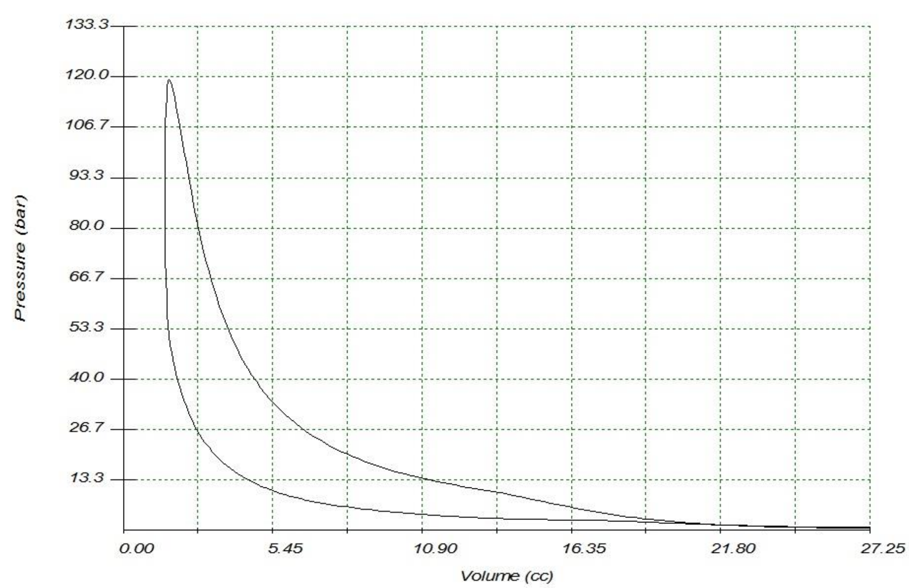
High Power Two Stroke Design Part 2

Before we continue our look at future directions in two stroke design, we need some basic definitions and some engine history. I'll use British engineering units for these examples. Engines were created to do work. Work is defined as moving a weight a distance, measured in foot (the distance) pounds (the weight). Power is how fast this work is done or foot-pounds per second. One horsepower is 550 foot-pounds per second. Since we're racing, power is the basic measure of engine merit we want to look at. The torque in foot pounds or amount of work an engine can do is found at a particular rpm by dividing the horsepower by that rpm and multiplying the result by 5252. This torque can always be increased with gearing to match your needs, but the power will not increase. Therefore, the work won't get done any faster.

Internal combustion engine power is closely related to the amount of working fluid (usually air mixed with a little bit of fuel and/or combustion products) passing through it. In piston engines this is the piston's displacement times the rpm. The combustion process in the cylinder increases the pressure of this air and it expands, pressing the piston down. The result of one revolution is a cylinder that decreases then increases in volume with a varying internal pressure. That's shown on the pressure volume diagram below. The area inside the graph represents the work produced in a single cycle. The average pressure acting on the piston is called the mean effective pressure. A more easily calculated figure of merit is the brake mean effective pressure, or the average pressure acting on the piston needed to produce the power measured on a dynamometer.

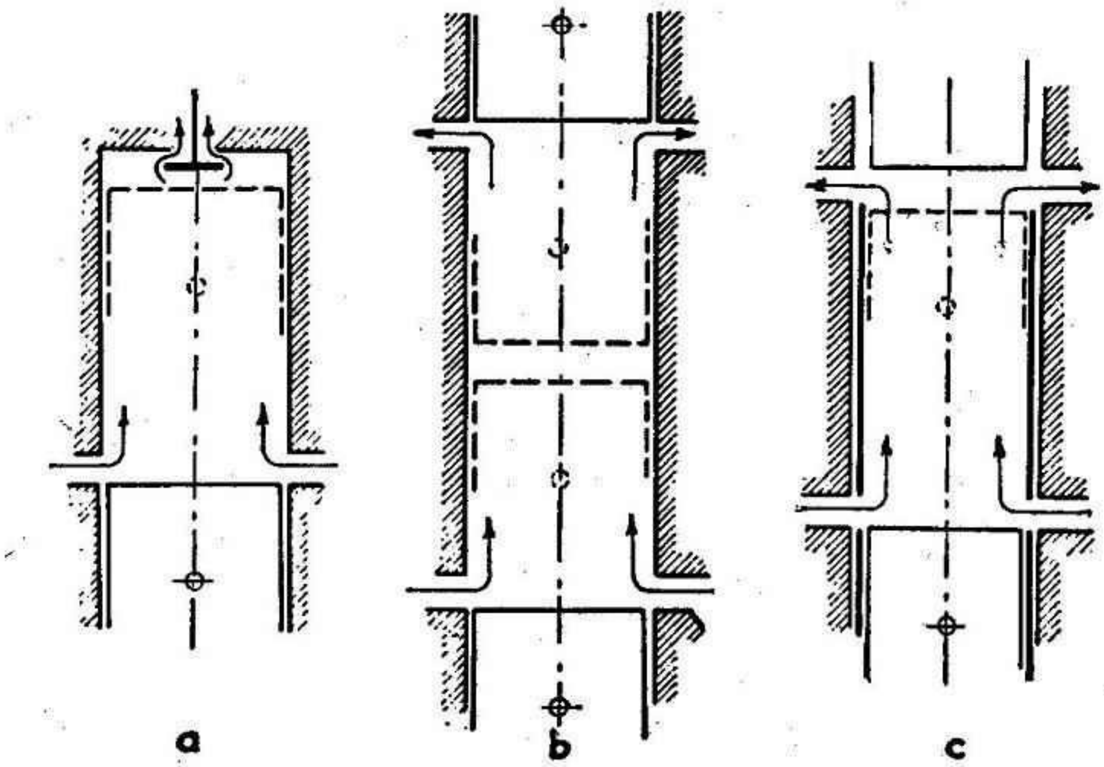


PV Graph

An engine's power can be increased by increasing the amount of air flowing through it and/or the brake mean effective pressure. The amount of air flowing through a piston engine is determined by the size of the cylinder (displacement), the air density, and the rpm. The brake mean effective pressure is determined by many factors including fuel heating value, air density, and the efficiency of all the various processes. These factors were recognized very early, and most racing classes limit an engines power by limiting the displacement, air density (amount of supercharging), and sometimes the fuel. That leaves increasing rpm as the only way to move more air through the engine. Increasing brake mean effective pressure is a lot harder, especially when fuel type is limited.

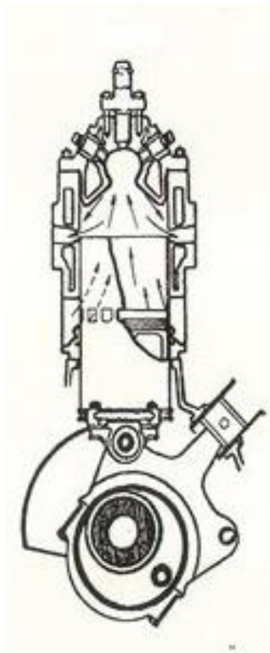
As was mentioned in part one, a two stroke's power is limited both by breathing (the ability to handle more air) and scavenging (the amount and purity of the mixture left after the exhaust port closes). Brake mean effective pressure is closely related to scavenging efficiency when everything else is equal. Even with major improvements over the last 50 years, loop type scavenging systems can't compare to a four stroke's scavenging efficiency. Our model engines along with small industrial two strokes have been stuck at break mean effective pressures of under 100 psi (7 bar) for a long time. Naturally aspirated four strokes seldom exceed 150 psi (10 bar). The best racing two strokes can reach 200 psi (14 bar) but the pipe is supercharging the cylinder. A top fuel dragster engine can reach 1500 psi (100 bar) with a combination of high supercharge and nitro.

Let's look at some other two stroke scavenging systems. Uniflow scavenging, where the incoming air enters at one end of the cylinder and pushes the exhaust out the other end, is the gold standard of two stroke scavenging systems. In the past, three methods of uniflow scavenging have been used, the poppet exhaust valve engine, the double piston engine, and the sleeve valve engine. See the pictures below.



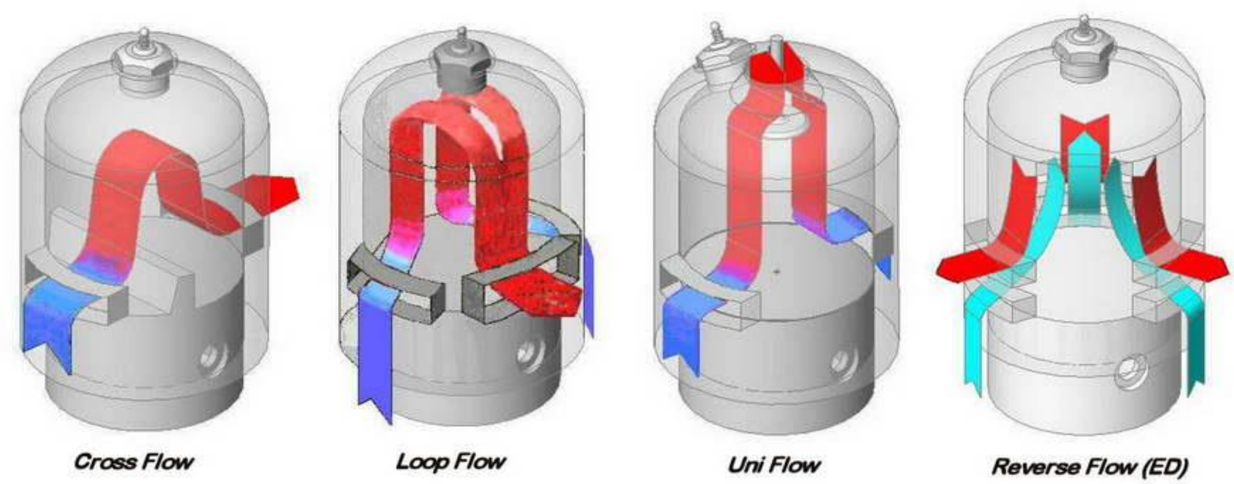
Schemes of uniflow scavenging.

Both the double piston and poppet valve exhaust engine are in use today, but both have limitations for high power use. The poppet valve flow is limited both by restricted area and opening speed, so the maximum rpm is limited compared to ports. Lots of large two stroke diesels use this system since high speed isn't needed. The double piston engine is mechanically complex, but otherwise has formed the basis of some very successful engines. See the Eco Motors engine illustrated in part 1. The sleeve valve is less complex and doesn't suffer from immediate rpm limitations. However, it has never been fully developed. Because the jet engine was obviously superior for aircraft, the development before and during World War II of the only two stroke engine using a sleeve valve, the Rolls Royce Crecy, was stopped. Single cylinder test versions of this engine were supercharged to brake mean effective pressures of over 350 psi (24 bar).

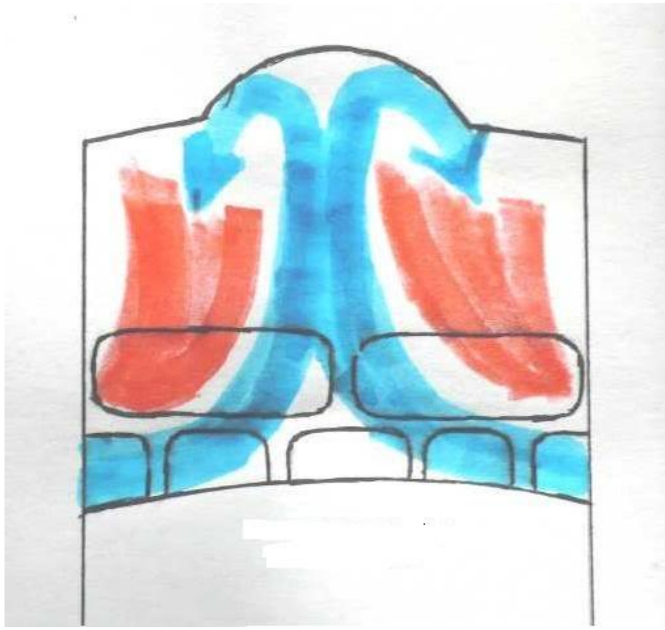
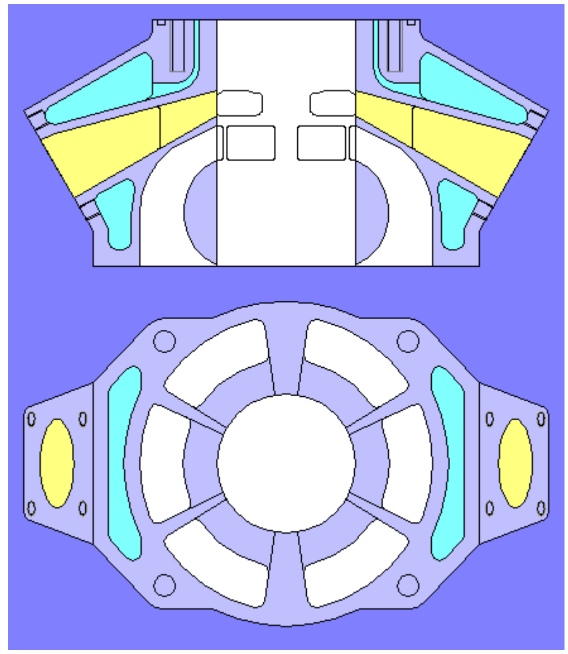


Crecy Sleeve Valve Cylinder

As was also pointed out in part 1, the tuned pipe, taking advantage of the pulsating nature of the two stroke engine, revolutionized two stroke thinking. Its performance made up for poorer scavenging in the simple engine. The picture below shows a comparison of the various types of scavenging systems used in simple engines. Model engines have used all but the uniflow type for a long time, but performance seems to be best with loop scavenged engines so far.

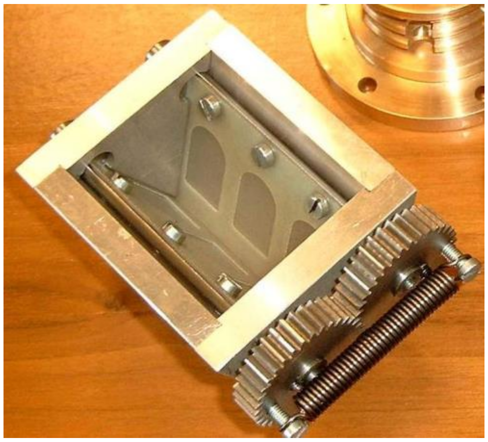


However, the type described as reverse flow scavenging is being reborn with modern ideas. The new version is called the FST or FOS scavenging system and is being tested in 50 cc racing motorcycles. The advantage is that both exhaust and transfer ports can wrap completely around the cylinder wall, giving lots of time area, especially blow down time area. This better breathing allows more rpm, therefore more power. The problem is creating a good scavenging flow with minimal mixing and little loss out the exhaust. The idea is illustrated below.

Notice the transfer and exhaust passages look very much like those of the Aprilia 125 except that they go completely around the cylinder. The problem is to create a stable column of air in the center of the cylinder to force out the residual exhaust. Is it possible with around the same scavenging efficiencies as the loop systems? Preliminary testing on a 50 cc motorcycle engine looks good.

The intake valve into the crankcase is another point of complexity and restriction in two strokes. Many valve schemes have been tried with piston ports and disk and shaft rotary valves favored by model engines. Larger engines mostly use piston ports, reed valves, and disk valves. Except for starting, why do two strokes need crankcase valves at all? It turns out that the crankcase acts as a Helmholtz resonator driven by the pulsations in the cylinder. Crankcase pressure rises and falls, drawing air into it without valves. Frits Overmars has described a reed valve system that acts normally at low rpm but can be opened completely at higher rpm, creating an open hole into the crankcase. He calls this the 24/7 intake system illustrated with an early prototype below. David Wilfong has removed the disk valve in a CMB nitro engine and run it successfully with no intake valve. Whether it develops more power is still to be tested.


24/7 Reed Valve

However, it's hard to get a reed valve to work in a small engine at the very low crankcase compression ratio that's best for the 24/7 system. A big disk or rotary valve only sacrifices a little peak power in simulations to the 24/7 system in a FOS style cylinder.

To take advantage of the huge time area the FOS scavenging allows, the engines need to run at high rpm. This could be over 30,000 rpm in a 26 cc engine. Doing this requires cutting edge mechanical design with the right bearings and materials. That will be covered in part 3.