

The Nitro Engine part 3

Again, according to a conversation I had long ago, the second most important part of the nitro engine after piston and sleeve fit is the cylinder head. This is largely due to the nature of glow ignition. A glow plug ignites the fuel and air mixture when it is compressed enough that the hot platinum element causes ignition. A lot of factors determine when this happens. The process is actually the same as preignition (NOT detonation) in a spark ignition engine. Diesel engines also use a heated plug to help ignite the fuel when cold. How rich the mixture is as well as the methanol to nitro ratio effects ignition timing. Other fuel elements like propylene oxide also effect ignition. However, with a consistent fuel mix, the ideal mixture can be adjusted easily for best power. That leaves the head's compression ratio as what sets the ignition timing.

The factor that determines this is the head volume. The ratio of the head volume to the total cylinder volume (head volume plus cylinder swept volume) is the compression ratio. As an example in a 26 cc Zenoah engine (actually 25.4 cc swept volume), the head volume is around 2.4 cc. That makes the compression ratio $25.4 + 2.4$ divided by 2.4 or 11.6 to 1. This is the geometric compression ratio, but the effective compression ratio is reduced by the time the exhaust port is open. Because of the effect of this exhaust timing, I don't know of any standard recommendation for compression ratios. Small, racing motorcycle two strokes can run geometric compression ratios of 19 to 1 on straight methanol. Racers, stuck with an engine and head combination, can use head shims to vary the compression to change the ignition timing over a narrow range. Most engine builders use the cut and try method of varying the volume of the head button to find the best result.

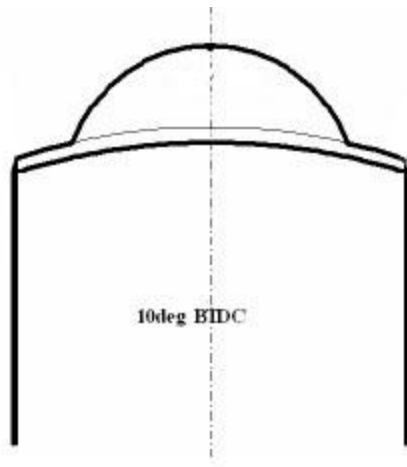


Head Buttons

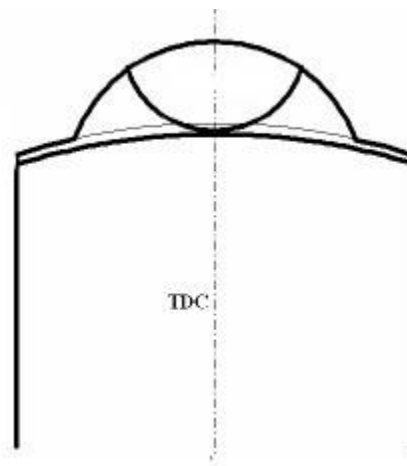
There is another factor that determines the character of combustion in the cylinder. The head consists of two areas, the squish area and the central combustion area with most of the volume. The squish area is very close to the piston at top dead center. This means most of the mixture is in the central area, close to the plug, and can be ignited quickly. The squish also forces the mixture into the central area as the piston rises, causing turbulence that enhances combustion. This close fit also cools the trapped mixture outside the central area, discouraging detonation. This is how the squish works:



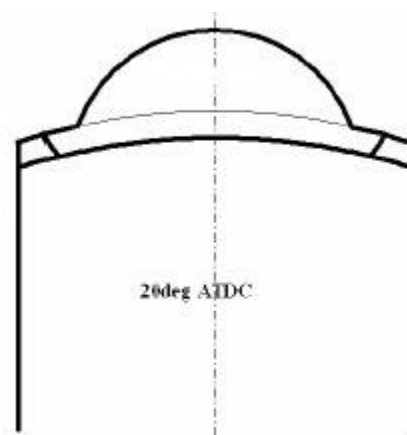
Mixture flow as the piston approaches TDC. The sharp edge between the squish area and the central volume encourages the flow across the top of the piston.



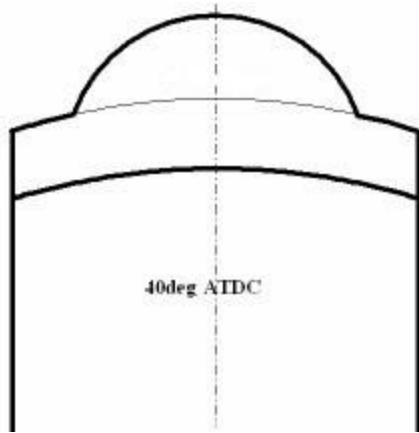
A point of flame starts to burn at 10 degrees before TDC.



This is the size of the flame front at TDC.

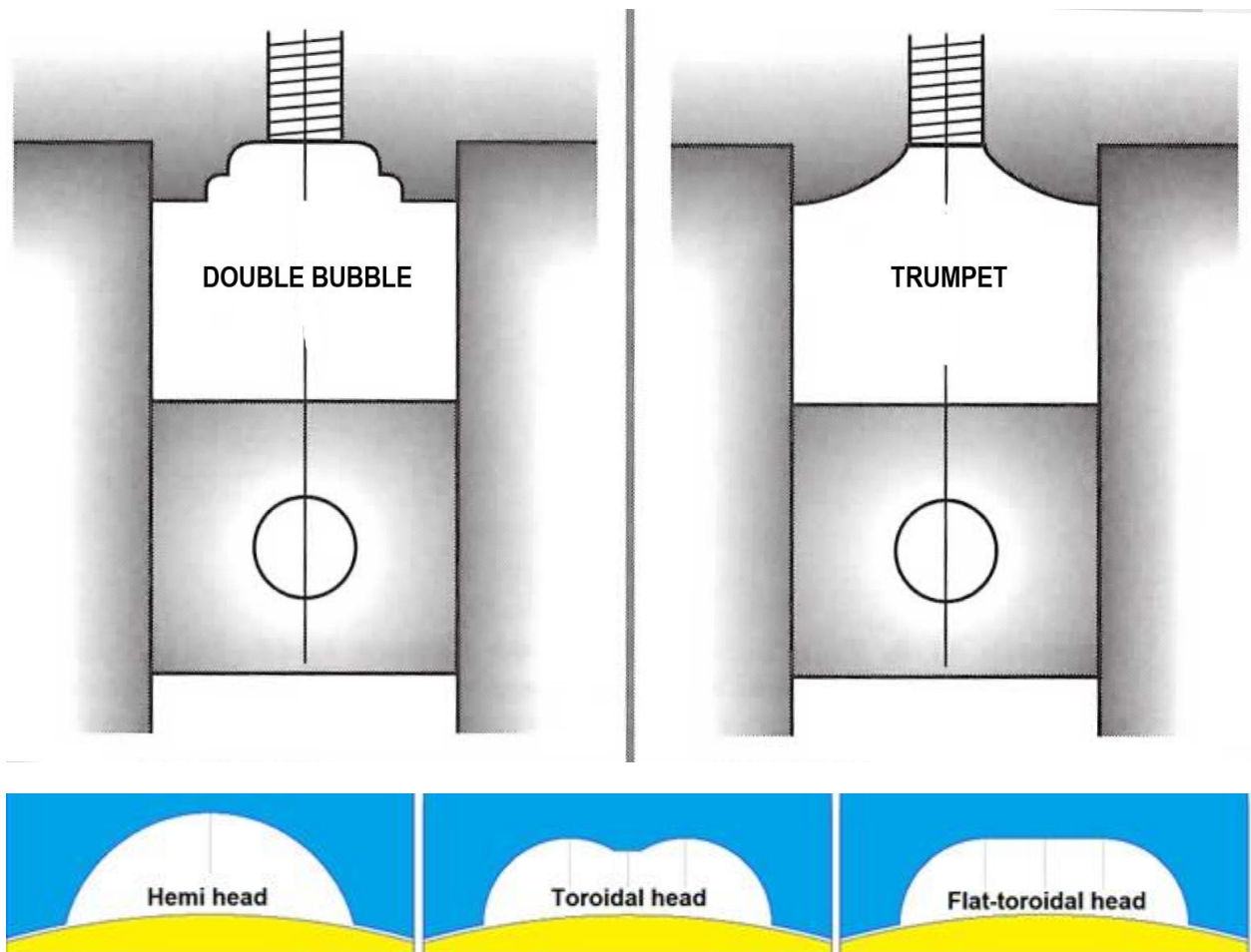


The flame front continues into the squish area at 20 degrees after TDC.



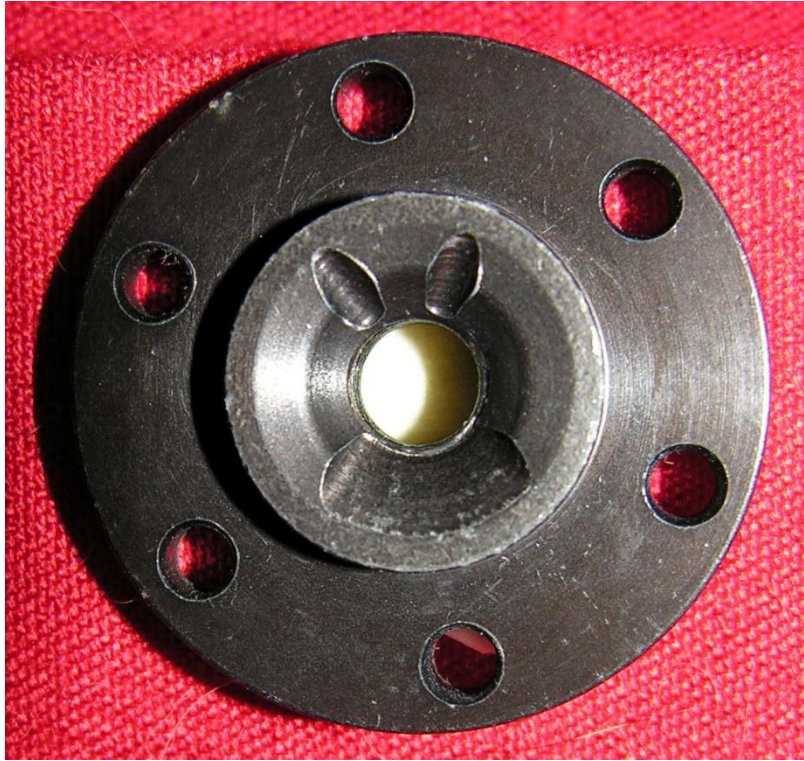
Combustion is complete at 40 degrees after TDC and the burnt mixture keeps expanding until the exhaust opens around 80 to 90 degrees ATDC.

A huge number of plug combinations and head designs have been tried. I'm only going to look at designs that work with modern Schnuerle scavenging engines. The distance from the plug element to the piston effects combustion. Pulling the element out of the plug for a few coils is a standard performance trick. This brings the ignition point more into the center of a hemi combustion chamber. The heat range of the plug also affects the ignition timing. Higher nitro fuels usually run best with a colder plug. Again, experiment is the usual way to find what works best.



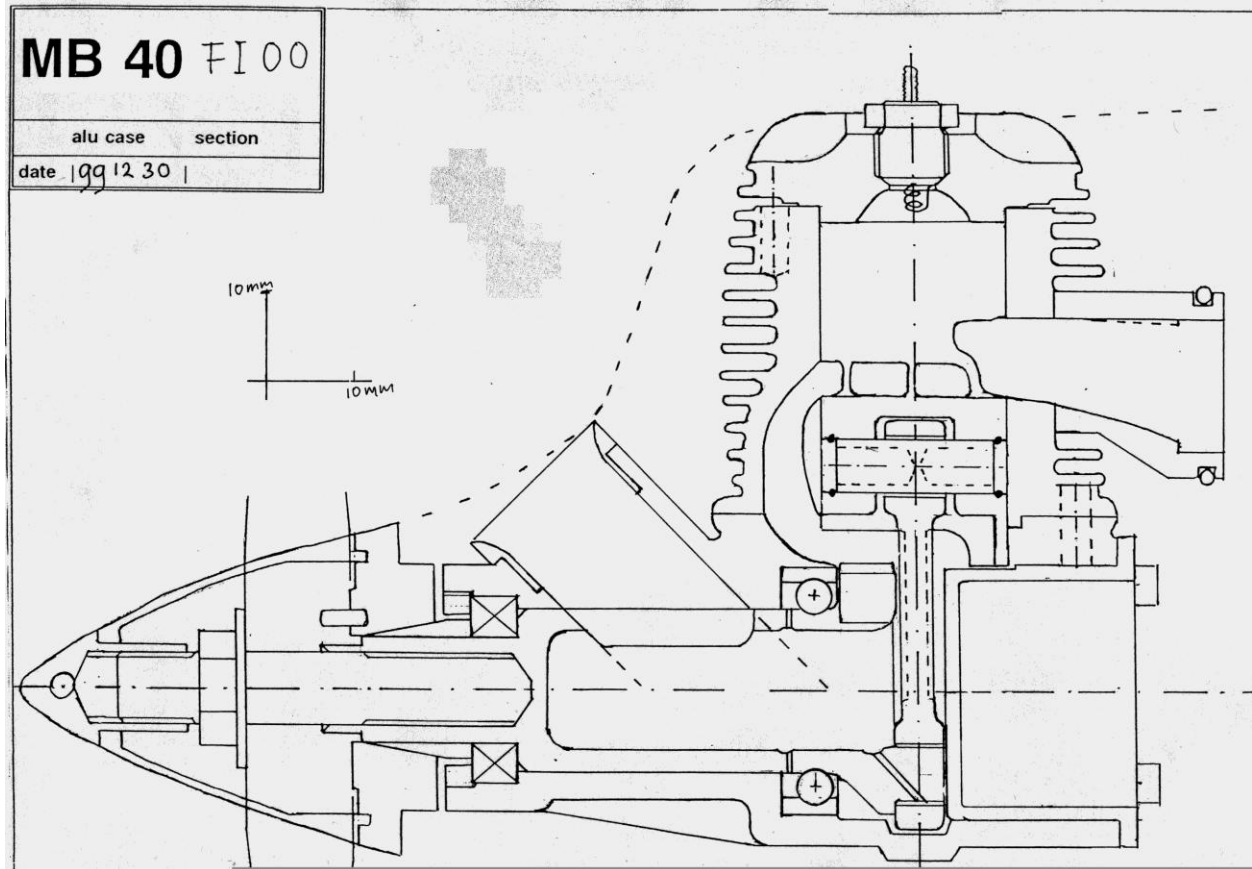
Head Shapes

The other issue in head design is scavenging. A two stroke engine's power is an excellent measure of scavenging efficiency. The flow from the transfers needs to sweep burned combustion products from the head into the exhaust. Typically the flow from the boost port does this. The head shape originated by Terry Keeley and "borrowed" by K&B is an example. The boost port flow sweeps up the small fingers and out the wider exhaust side. The angle between the narrow squish band and the central volume also helps. This design is reported to add a few thousand rpm over the standard head button.

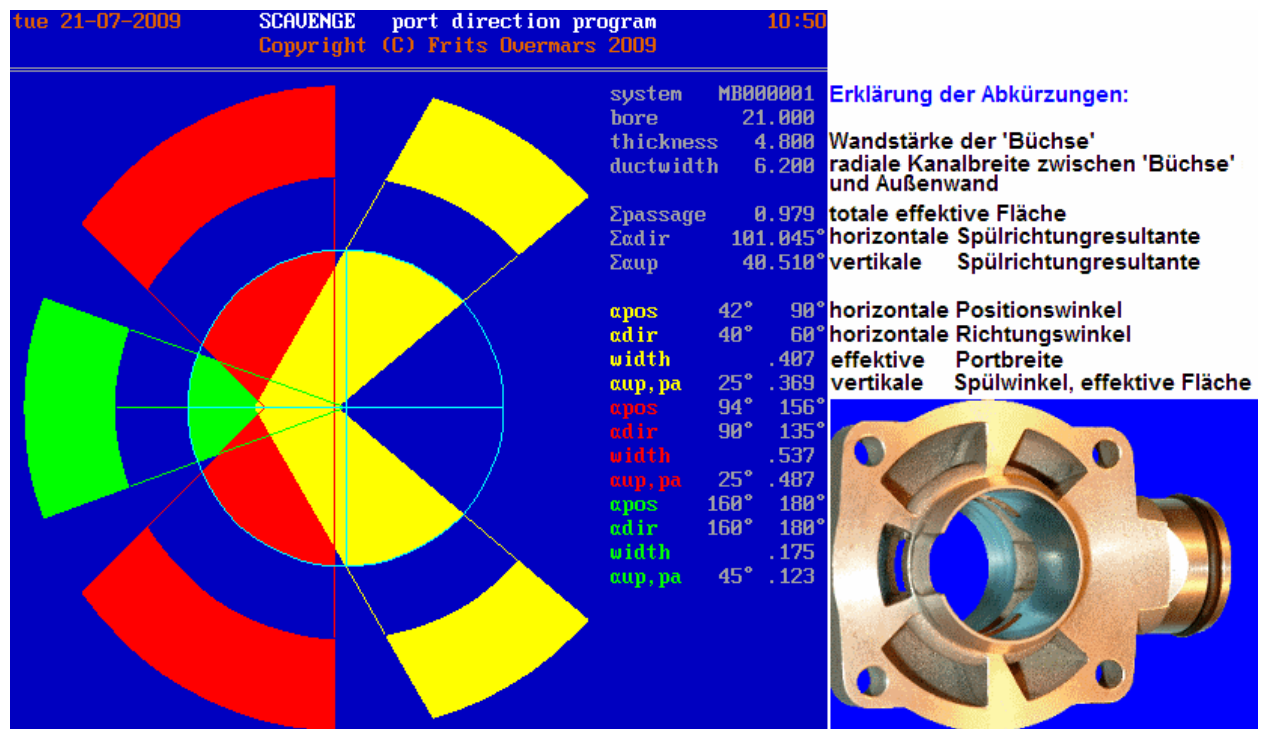


Keeley Head

The best squish action should come from a wide squish band with a sharp corner between the squish area and the central volume. The best scavenging should come from a narrow or no squish band with a blend radius into the combustion chamber like the trumpet head. Shallow chambers should also scavenge better. Toroidal and flat toroidal (bathtub) heads often are superior to the standard hemi head because of this. So what works best? It depends on a lot of factors that vary from engine to engine. Modern 5 port transfers are very good at directing the incoming mixture. With this and a really effective pipe, you can run a wide, sharp edge squish with high compression and get good power. However, only one nitro engine I know of, the Profi MB 40, has modern transfer passages. It has a standard hemi head with a wide squish. All others use transfer passage shapes that were found to be very poor in tests at the Queens University of Belfast decades ago. Still, the trend is toward a squish area nearly 50% of the bore area with sharp edges. Some testers have found power gains with the torodial or flat toroidal head designs and even trumpet shaped combustion chambers with very little squish band.



Profi MB 40 Cross Section



Profi MB 40 Transfer design

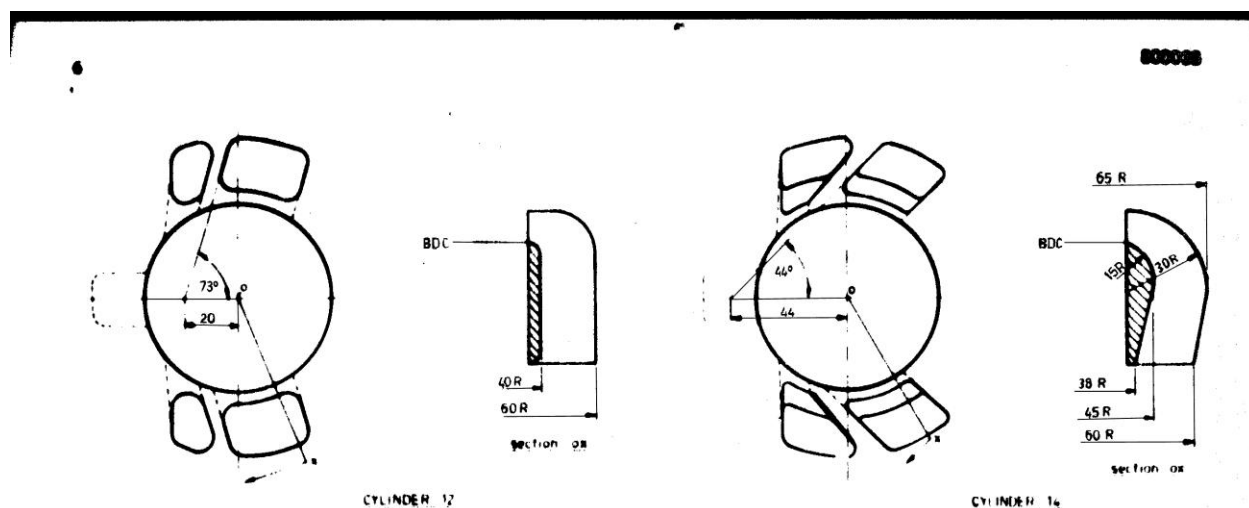


Fig. 4c - Transfer port layout for cylinder 12

Fig. 4d - Transfer port layout for cylinder 14

QUB Cylinders for Yamaha Showing a Poor #12 and an Excellent #14 Transfer Design

The plug seal is another area for performance gains. The so called "turbo" or Nelson plug that seats on a taper at the base and not on a gasket has been shown to add several thousand rpm. See the Profi engine cross section for an example. Head cooling is another neglected factor. Small engines, especially on outboards, are over cooled. Turning off the cooling water as well as trimming fins on air cooled heads can add power. Ideally the squish area and the plug should be cool, but the combustion chamber needs to be hot to prevent heat loss. This was done in the head button pictured with a broad area over the squish and narrow grooves over the combustion chamber leading to a groove around the plug. Racers often drill a hole that directs the water leaving the head over the outside of the plug for cooling.



Squish Band Cooling

How can you find the right combination? A series of standard air propellers have been used by engine builders to measure power for a very long time. Since the propeller absorbs power as the rpm cubed, a small rpm increase with a given propeller shows a large increase in power. An inertial dynamometer is more complicated but even better. In the field you can read the plug and head to get an idea of what is happening.

Test with a new plug. The plug element should be lightly frosted and not distorted. A shiny plug element indicates a rich mixture. If the element is distorted the compression may be too high. Try adding a head shim. A broken or missing element usually means the mixture was too lean. The engine will often continue to run with a broken element, but the plug won't glow with the glow igniter. Detonation shows up as sand blasted appearance on the squish and piston crown. Detonation happens when the compression is too high and the mixture explodes rather than burning with an advancing flame front as in the squish action example. This explosion not only greatly increases heat flow, but also scours away the cool boundary layer protecting the piston and combustion chamber. The greatly

increased heat flow to the piston can result in a hole or melted area on the exhaust side. Most engines can stand small amounts of detonation without failure. The K&B head with the light frosting pictured ran without problems. The second picture shows what severe detonation can do. Note the signs of overheating on the exhaust side of the holed piston pictured.



Light Frosting from Detonation on a K&B Keeley Head Copy.



Holed Piston from Detonation

All the above discussion has been for head designs that give the most power. Control line acrobatic engines have very different requirements. They need to maintain constant rpm to maintain constant speed under varying loads. That has been described as a 2-4-2 pattern where the engine alternates between firing every and firing every other revolution. To achieve this they run rich with the muffler or pipe design helping to maintain constant rpm. One Swiss engine builder has experimented with several head designs for these conditions. The challenge is to keep the engine firing while the very rich mixture cools the plug.



Head with Plug Shield



Double Plug Head

With the rich mixture, raw fuel droplets can quench the plug. The double plug design was the first try, but the titanium plug shield worked better. Placing the squish area on the exhaust side helps cool the hot side of the piston without blocking the boost port flow scavenging the combustion chamber. He feels that a plain dome with no squish band may work as well since scavenging seems to be more important than the squish effect.

The next part in the series will explore the flow through the engine. I will examine intake, transfer, and exhaust design.