



[Home](#) [Message Boards](#) [Photos](#) [Videos](#) [Reviews](#) [Classifieds](#) [Arcade](#) [Contact](#) [Advertise](#)

[GoFastNews.com - All Racing News All the Time!](#) > [General Discussions and Site Information](#) > [Technical Articles](#)
[Turbulence and Combustion Dynamics](#) **Turbulence and Combustion Dynamics**

User Name ☐ Remember Me?
 Password

[Register](#) [Blogs](#) [Gallery](#) [FAQ](#) [Community](#) [Calendar](#) [Today's Posts](#) [Search](#)

Technical Articles Learn from our staff of Technical Writers!



[LinkBack](#) [Thread Tools](#) [Display Modes](#)

08-28-2007, 07:24 PM [#1 \(permalink\)](#)



[DavidVizard-GFN](#) **OFF**
 Pit Crew

Join Date: Apr 2007
 Posts: 840

#1 -Turbulence and Combustion Dynamics

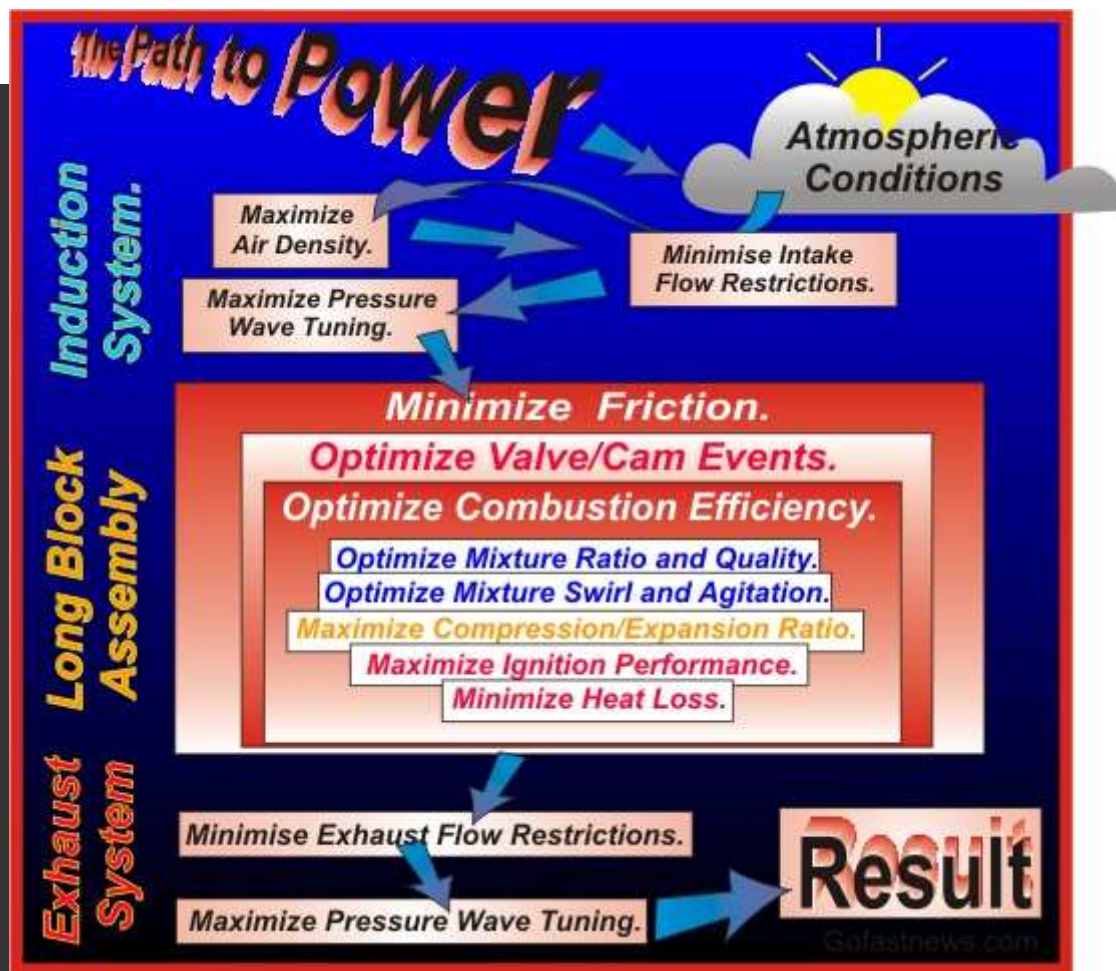
#1 Turbulence and Combustion Dynamics

Cramming a cylinder full of air is just one aspect of making power. Once filled it still has to be burned effectively.

Text, Photos and Drawings
 By
David Vizard

Before getting into mixture dynamics in depth it's necessary to have everybody on the same page when it comes to the term 'combustion' as related to engines. I want to make sure that each reader understand's so I make no apologies for what may appear to some to be oversimplification.

First let's look at the overall picture. The following chart is the summation of all you need to know about power production.



The chart shows that the Long Block Assembly has more factors to take care of in the 'Optimizing Combustion Efficiency' box than any other box. Here we have to take care of the five issues within that box. That will be our goal here and to start let's take a basic look at what goes on in the cylinder.

The first point to note is that the cylinder's charge does not explode when the plug fires. It burns - and it in no way resembles an explosion. In a Cup Car engine at peak rpm, the charge across a 4-1/8 inch bore burns at approximately 150 mph. An explosion is something that ignites at over 2000 mph and dynamite burns a whole lot faster than that. At a 700 rpm idle the flame speed barely makes 10 mph! This is why we have distributors with ignition advance curves.

"It's an explosion that pushes the piston down the bore" - "it's the burning fuel that pushes the piston down the bore not the air -it's there just to support combustion". These statements and many more demonstrate that a working understanding of what is involved is not as common as we might at first believe. Before we can look at, and hopefully optimize, the combustion process we need to understand first principles. The easiest way to do that is to start with an external combustion engine i.e. a steam engine (combustion takes place outside or external to the working cylinder).

Two factors make a steam engine work. Combustion of fuel to generate heat - and a working medium. The fuel can be oil, coal or wood but in every case the working medium is steam from water. By heating water to super heated steam a high pressure is created. This high pressure is then applied to a piston/crank mechanism and turned into motive power. The key factors to note here are 1) the generation of heat and 2) a working medium.

Now consider an internal combustion engine. For 'Internal Combustion' we could substitute 'internally generated heat source'. Let's do just that. Imagine a cylinder full of air that has been compressed by the piston going to the top of the bore. Instead of burning gasoline to provide the heat we will substitute a piece of thick wire and put 12 volts and 1000 amps through it. Assuming it is suitably sized the wire will act like a fuse and instantly vaporize. The heat it produces will expand the air such that a typical size V8 cylinder will, on this power stroke, generate over 50 hp. From this you can see that the pressure on the piston is caused by heating the air and it's this hot air wanting to expand that pushes the piston down the bore.

Unlike a steam engine, which uses air only to provide the oxygen for combustion, the air taken into an internal combustion engine has to serve two purposes. Firstly, it has to supply the oxygen for

combustion and secondly it has to be the working medium, it. My point here is that it is the heat of combustion expanding the air that supplies the power. If, a moment after combustion we could, by some means suck all the heat out of the air within the cylinder, the pressure would immediately drop back to whatever the compression pressure was at that point in the stroke.

So what we can say for sure at this point is that not only must we fully utilize the heating value of the fuel to generate the most heat possible but also make sure that after producing heat we don't aimlessly squander it through unnecessary losses. All this falls under two headings – combustion efficiency and thermal efficiency. Let's define those two parameters here so we are all on the same page. First combustion efficiency. In the context we are dealing with here we can define this as the amount of fuel that was burned in the cylinder divided by the amount that could have been burned within the cylinder for the oxygen content involved. As for the thermal efficiency - that is the amount of power developed at the flywheel divided by the amount of power that could have been developed had all the heat energy of the fuel been turned into mechanical work.

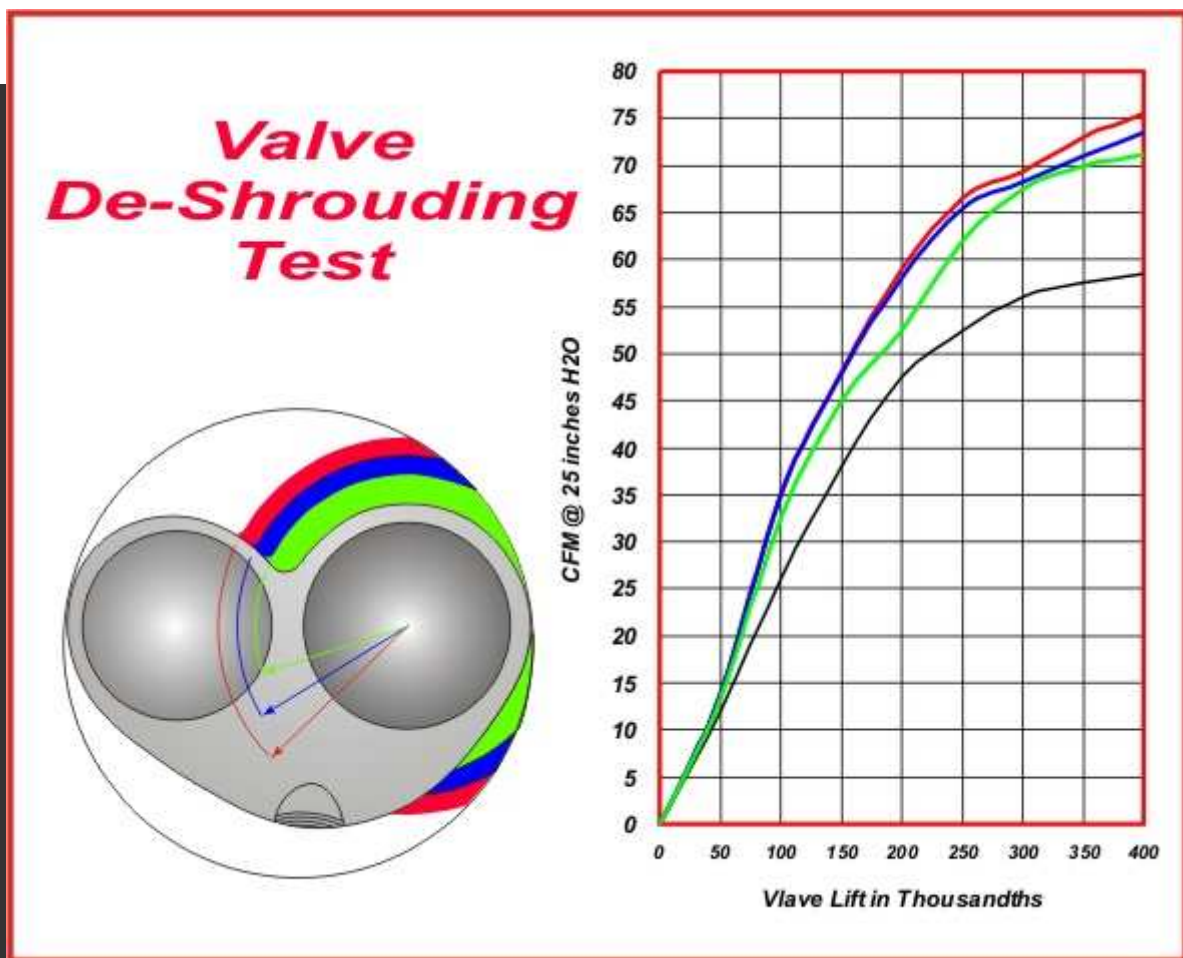
Defining Goals.

OK with the basics laid on the line let's look at where we are going to go from here. At this time I need to point out that I do not have access to the sophisticated and diabolically expensive equipment that the big auto makers have to do combustion research. With the test gear I have I'm more in the 'super equipped Hot Rodder' category. The plan here is to bring to bear what is now nearly 50 years of race engine building and development experience so that you at least know what I know. The bottom line here is that we will look at the things we can, as hot rodders, practically apply to make our engines better. There won't be too much SAE type hard core stuff unless we can physically apply the info gleaned from such sources.

Now all the preamble is about over I will make a start on combustion efficiency by dealing with some pertinent personal experiences over the years I have been hopping up engines.

In the Beginning.

In 1958 I made my first attempt to modify a cylinder head with the aid of a means to flow test it. The head concerned was the Harry Weslake designed head intended for the BMC (as it was then) 'A' series engine that the following year powered the original design of Mini. This head had a heart shaped chamber that, according to the technical press of the time, had near magical combustion properties. In hindsight I wonder if they really had a clue as to the reality of the situation. At the time I was equally guilty of being sucked into this belief to the extent I figured no one was likely to make such a complex chamber form unless there was some advantage to it (and if there was I never found it). So with all the mods done to improve flow I studiously avoided any radical alterations to the combustion chamber.



The graph shows the increase in airflow as each successive color band is cut from the combustion chamber. Note the diminishing returns.

My efforts with these heads seemed to produce results as good as those guys who had already been doing heads for years so I stuck to a near stock chamber shape. About 1959 I began to have a better understanding of valve shrouding and that the Weslake design suffered greatly from it. So the question here was what would the trade off be by deshrouding the valves for more flow and possible reducing combustion efficiency from the radical reshaping done. Since the deshrouding bumped airflow by a big margin I thought I would give it a try. With the same CR the head with the heavily reshaped chamber delivered no less than a 50% bigger increase than the head that largely preserved the original form. That is it delivered a 12 hp increase at the wheels instead of 8! (We are talking of an 850 cc, 5 ports for 4 cylinders, engine here). Since we were now up from 20 to 30 plus (at the wheels) with little more than a cylinder head swap I was beginning to question the integrity of the original Weslake design that had been heralded the product of a genius. Who knows, Weslake may have been a genius (Check out his auto biography 'Lucky all my Life') but the 'A' series head was beginning to not look like a genius design.

At about this point I began to chase air flow at the expense of almost any other factor including compression ratio. And working on those 5 port 'A' Series heads sort of clouded the situation. The engines they were used on were, in the main, so starved of air that any airflow increase made a measurable positive difference even if there was a negative impact else where. In truth these heads were so flow starved and the engines responded so well to any improvements, that half of the UK's head porters figured they were at the very least, brilliant and gifted. For many, a devastating reality check came when they attempted to port intrinsically better designed heads. Those who applied real world engineering logic and/or some kind of flow check on results generally managed to stay ahead of the game.

As poor flowing as these 'A' Series heads were though a valuable lesson was learned about not taking things for granted. Throughout the 60's the hot ticket for induction on the 'A' series engine was a big side draft 2 barrel Weber carb. These things really snorted (and that's not a figure of speech either). About the late 60's the Dellorto side draft carb, a Weber look alike design, began to filter into the UK. The innards looked a lot more sophisticated than its Weber counterpart and, for a given venturi size, it flowed more air. So I figured that since it would bolt right in the same place as a Weber I would give it

a try. However, before I could get down on Tecalami's dyno in Plymouth I happened to talk to ace mini racer (the guy was, when behind the wheel of a Mini, apparently blessed by God!) Richard Longman. It appeared that only a week or two before he had been down to the Plymouth dyno to test fuel injection and Dellorto carburetion on a race engine similar to the one I was going to test. He reported that on his engine, the Dellorto lost 8 of it's 128 hp and 10 on the fuel injection. Frustrated as to why, was it air or fuel mixture preparation, he put the injector nozzles into the Weber carb bodies. Guess what – that engine still lost 10 hp over fuel delivered by means of the carb's own fuel system.

I thought that the loss of power with the carb/fuel injection change might be a peculiarity of a Longman spec engine so I went ahead and, as it happened, against my better judgment, did my own dyno tests. The results mirrored the Longman tests. I now had a burning question that defied an immediate answer. Why did delivering a more finely atomized fuel spray cause the engine to drop so much power? The Weber carb was, in truth, not so good at atomizing the fuel - it came out of the auxiliary venturi (booster venturi) in globs rather than anything that resembled a spray. Yet that 'A' Series engine loved it, and too this day, I have never figured out why globs (yes - globs) work and even a moderately good spray does not. I put this down to the fact that there is always more to anything than meets the eye!

The Chrysler Saga

1970 rolls around and Chrysler UK intro's an interesting car – the Avenger - and somehow or other I got involved with the factory doing development work as an outside contractor so to speak. The Avenger was basically an all new, from the ground up, machine and came in two and four door form. The engine was designed by a genius – John ----- and I have just forgotten his last name. If you had asked me yesterday I could have told you but right now it escapes me. Anyway John had designed an engine intended to be as environmentally friendly as possible short of having a catalytic converter on it. The combustion chamber on this engine was, for a modern engine at least, unconventional. It was formed by the piston stopping about a ¼ inch short of the top of the bore. The head itself had no chamber in as much as it was flat. It was, in fact a quenchless chamber. The intake ports on this head, which were on the same side as the exhaust port, were very strong on flow. I was supplied one of these cars for the princely sum, in today's money, of \$5. It was a two door GT with 7 miles on it. Later that year Chrysler brought out a hopped up version of this car equipped with twin side draft Weber's and a ported head. This, together with some suspension upgrades and styling mods, was introduced as the Avenger Tiger. The plan was it would go head-to-head with Ford's Lotus Cortina Twin Cam. Although it matched the Lotus Cortina for handling, braking and cornering it was just a tad down on power to out drag it.

Any way - back to the Avenger GT that I had to work with. To get a good part throttle burn and clean exhaust the intake charge, delivered by the twin inch and a half Stromberg's, was heated. This was achieved by having the intake manifold bolted to the exhaust manifold. Between the two was a 1/16 thick plate with a hole in it. Through this hole the exhaust flame physically played onto the under side of the intake forming a very hot spot. This, at part throttle probably was sufficiently hot to vaporizing all of the fuel at any sane street or highway driving speeds. OK this might sound like stock boring stuff but now we come to the crux of the matter. My first discovery was the if the hot spot was semi eliminated by replacing the 1/16 thick plate with a hole in it by similar plates with no holes the power dropped from 78 RWHP to 74 even though the charge temperature dropped a whole bunch. With a quenchless chamber I thought that this might be the case and this test suggested to me that this type of chamber needed to have a fair amount of vaporized fuel and the rest delivered in really well atomized form.

This year I had planed on drag racing the car at Santa Pod in a class that can best be described as 'improved street stock' This class allowed the head to be ported, Any intake and carb combination that was available off the shelf could also be used. On the exhaust side a race exhaust system was permitted. The cam and valve train had to remain stock as did everything else below the block deck face. The factory offered a twin side draft 40 DCOE Weber kit for this car which Chryslers race team manager, the late Des ODell, gave me to test. Knowing that this engine liked fine fuel atomization and that the Dellorto DHLA carb (a Weber look alike) delivered much finer fuel atomization I got a set to try on the chassis dyno along with the Weber's. The difference between the finer fuel atomization of the Dellorto's and the more blob like delivery of the Weber's produced a night and day situation on the dyno. I wrote a story about the A-B test involving these two brands of carb and Weber's UK's boss apparently went ballistic – told people I did not know what I was talking about – the tests were rigged etc. it sounded to me he was just one step shy of putting out a contract.

The first drag race I did with the Avenger was somewhat amusing. I turned up at the track with this car, viewed by 99% of racers at the time as a shopping vehicle, and the jokes were rampant. Yep - I was the guy to laugh at – before the racing started that is. After putting every one on the trailer – with ease - there weren't even any smiles as far as I could see. Even 1600 cc four valve per cylinder Cosworth BDA Escorts went down to the two valve, 1500 cc pushrod, all iron engined Avenger.



I could have shown you a shot of the car parked or in action. Action won out. Just for the record this flame burnout was a result of the top fuel guys betting me a stocker could not do a flame burnout. They lost a fair chunk of \$ change \$ on this one!

I continued to develop this engine and by the end of the year had it running really well by paying close attention to mixture and ignition properties as well as overall airflow. The useful power band was from 400 rpm to 8000. This engine had punch anywhere in between those two numbers and would, even today some 30 years later, put any variable valve timing Honda to shame for sheer drivability. A road test done by Clive Richardson of UK's Motoring News was of interesting in that it showed this car capable of 0-60 in just under 6 seconds and 0-100 in 17. Another test done by Motor magazine at the Lindley proving ground just outside of Coventry, England, demonstrated how strong the Avenger's super wide power band was. When compared to the figures delivered by a Ford Cosworth BDA Escort not only were the 'through the gears acceleration significantly better (over a second faster to 60 and three seconds faster to 100) but also the high gear 20-40, 30 to 50, 40-60 times were so much faster than the Cosworth that they did not publish them. The Avenger would pull hard from a little over 10 mph in high gear. The Cosworth Escort would not pull down low enough to even do the 20-40 test.

That Avenger engine was not just about outright peak numbers but a huge area under the graph.

So what produced this Avenger's steam engine like low speed torque and race winning top end? It was not small intake valves as some suggested. It was not a reconfiguration of the engines big bore short stroke to a small bore, long stroke. Nor was it countless other erroneous old wives tales for moves that are supposed to produce a torquey engine. For the record straight long strokes do not make more low speed torque than short strokes. I can disprove the 'it must make more torque because of the long arm' fallacy both mathematically and from dyno tests. Also the valve size thing cropped up so many times I was ready to about tear my hair out. I was even fed this size the valves for the power band fallacy at a Superflow Conference. I am going to be really categoric about this that to make best low speed torque the engine needs the valves to be as big as can be crammed into the space available.

Well so much for what it 'was not' that made the wide torque band a reality. The real world factors were about as follows. First a head with really good flow and as much swirl as I could find, although, it was still only about average in that quarter. Second, valves that used almost the entire cylinder diameter and since this was a short stroke engine the bore was big for a 1500 cc unit and that meant the valves were too. Ports the appropriate size (very important). Great attention was given to the twin two barrel side draft Dellorto 40 DHLA carbs auxiliary Venturi's to ensure a uniformly fine fuel atomization. An independent runner induction (one barrel per cylinder) and a well specced exhaust system in terms of lengths, diameters etc. All this produced, even at very low rpm, a highly combustible mixture in the quenchless chamber shape this engine had. The final frosting on the cake came from a diligent calibration of the mechanical and vacuum advance delivered by the distributor.

If I had to isolate one factor that contributed to this engine's wide ranging performance it would be it's obviously superior to the norm, in cylinder mixture dynamics.

Let's take stock of the situation here – the first engine we looked at – the Mini's 'A' series engine, liked big lumps of fuel. The second, the Avenger engine, liked really small droplets. What this suggests at this point is that there is not quite a clear cut route toward producing the best approach to optimum in cylinder dynamics.

I may not have understood but a fraction of what was needed about combustion dynamics at this stage but one thing was for sure. Just knowing a little more than the opposition not only allowed me to make

my car go significantly faster but also to slow all the other Avengers in the class I was to race against on road course the following year.

Just how that plot was perpetrated you will learn in the next installment of this series.

David Vizard

Last edited by DavidVizard-GFN; 08-18-2008 at 08:05 AM.



09-01-2007, 10:57 PM

#2 (permalink)



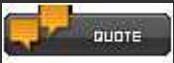
RMinOZ OFF
Garage Sweeper

Join Date: Aug 2007
Location: Adelaide, Australia
Posts: 8

Quote:

Originally Posted by **DavidVizard-GFN**
Just how that plot was perpetrated you will learn in the next installment of this series.

Cooooool



09-01-2007, 11:02 PM

#3 (permalink)

MadBill OFF
Garage Sweeper

Join Date: Sep 2007
Posts: 76

Quite an eye-opener. Over the years I had slowly come to the realization that the trade-off between atomization/vaporization for good combustion vs. the negative effect on volumetric efficiency due to the air displacement effect of too much fuel vaporization outside the cylinder was impacted by carburetor characteristics, fuel distillation curve, induction air temperature and manifold heat, but now it is revealed that combustion chamber attributes are of equal or greater import! Another layer of the onion peeled away...



12-22-2007, 12:23 PM

#4 (permalink)

Catherwood OFF
Garage Sweeper

Join Date: Dec 2007
Location: Palm Harbor, FL
Posts: 4

just a quick look at combustion. gasoline is flammable in air from 1.4% to 7.4%, about 55:1 to 13.3:1. 4 ways to put out a fire are stop the fuel, stop the air, stop the heat and add a chemical that suppresses the combustion process. combustion in the piston chamber of an engine uses the fuel and air. the piston going down will take heat away. octane boost will be the chemical suppressant. for the most efficient combustion the pressure has to build to max atdc before very much piston movement takes place. the faster the better. the faster the burn, the better. higher compression is also better.



01-16-2008, 06:52 AM

#5 (permalink)



Devious OFF
Garage Sweeper

Join Date: Sep 2007
Posts: 73

Quote:

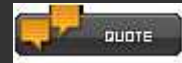
Originally Posted by **DavidVizard-GFN**

Well so much for what it 'was not' that made the wide torque band a reality. The real world factors were about as follows... Ports the appropriate size (very important).

What guides your decision in the port size for a particular engine and use? Displacement per cylinder? Peak torque rpm? Peak power rpm? Internal geometry and cam specs?

I see a trend today towards ports that are larger than what I would consider optimum for many street/strip cars and bikes chasing port flow and peak power numbers at the expense of velocity and a well shaped torque band with good area under the curve.

What are your guidelines on this?



Bookmarks



Digg



del.icio.us



StumbleUpon



Google



Propeller

[« Previous Thread](#) | [Next Thread »](#)

Posting Rules

You **may not** post new threads
You **may not** post replies
You **may not** post attachments
You **may not** edit your posts

[BB code](#) is **On**

[Smilies](#) are **On**

[\[IMG\]](#) code is **On**

HTML code is **On**

[Trackbacks](#) are **On**

[Pingbacks](#) are **On**

[Refbacks](#) are **On**

[Forum Rules](#)

All times are GMT -4. The time now is 12:34 AM.

[Contact Us](#) - [Home](#) - [Archive](#) - [Top](#)

Powered by vBulletin® Version 3.8.0
Copyright ©2000 - 2010, Jelsoft Enterprises Ltd.
Search Engine Optimization by [vBSEO](#) 3.2.0
Copyright ©2007 - 2008 GoFastNews.com LLC