Porting School #7 - Power & Port Volumes

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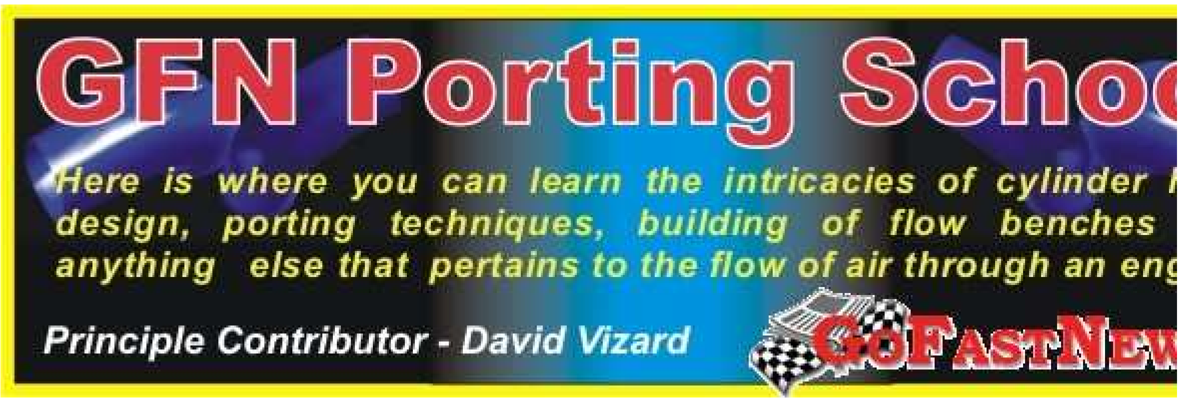
07-17-2008, 12:04 PM

DavidVizard-GFN OFF
Pit Crew

Porting School #7 - Power & Port Volumes



#7 - Port Volume

It's Effect on Torque and HP.

By
David Vizard

Dyno testing by David Vizard and Mervyn Bonnett

What you need to know to establish just the right port volume f small block Chevy or Ford engine build.

(And in case you wondered we will deal with **port** velocity in a more universal manner to cover all eng School #8)

Question – how many times have you heard it said that an engine is nothing than a simple air pump? If this was really the case then output should equate directly to the fl alone. In a nut shell bigger numbers would mean bigger power. If it were that simple I for one would b Unfortunately reality is somewhat different. The physics involved toward building a successful high outp engine is far removed from that of a simple air pump. The principle reason pushing the so-called 'simpl scenario into complexity is the dynamic 'stop – start' nature of the flow through the engine. The piston pressure waves force rapidly changing rates of flow and air pressure at key points within the induction tracts. Under such circumstances effects caused by both the momentum and the pressure waves gener completely alter the picture to the extent that for a given displacement and rpm, there is a certain **size** sectional area) of **port** that is best for the job. Anything more than a few percent bigger or smaller is r

Except for removing the march belt drive system here is our T & L built 383 small block ready to go. Other than looking it there is nothing exotic here – it's just a well specced u (click on one of their ads for more details) can replicate for you - minus headers – at less t turn key form.

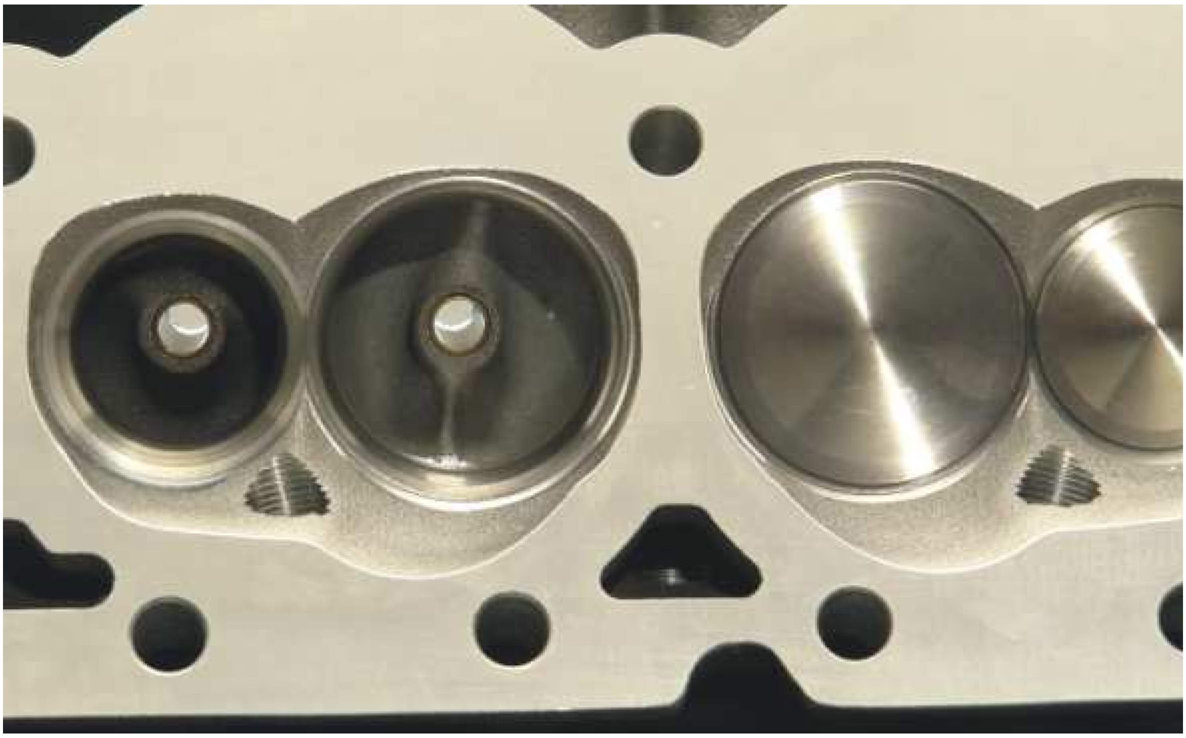
What I intend to do here, courtesy of the good guys at Dart, is to determine the effect various **port** siz typically moderate budget street/strip small block Chevy engines power curve. Because of the close res the small block Fords **port** dimensions this also closely applies to the Ford offering. But before we start stuff let's look at why, in the US, **port** sizes are quoted by volume in cc's.

Back in the days when there were no aluminum heads to speak of building a set of race heads involved grinding work on production iron heads. I remember porting my first set of serious Chevy race heads ir Lola T70 back in about 1968. It seemed as if I had forever in those heads. They proved a winning facto but the amount of time involved meant they were not the cheapest of items on that car to produce. Th scenario for most pro head ported back then and, to justify what they were charging the customer, it s the norm to quote the before and after **port** volume to highlight just how much work had gone into th process. Also since all the heads involved on small block Chevy's had a 5 inch intake centerline length c **port** volume also gave a loose measure of the **port** cross sectional area involved. Because of the ports shape as it progresses from the manifold face to the **valve** it was not entirely practical to quote a cross as there was always the question of the position of the quoted area. So, right or wrong, the **port** volur viewing **port** sizes became convention. So long as you do not loose sight of the fact that it is really the sectional area that is the criteria here then you won't go far wrong with the **port** volume method but b that these days ports of lengths other than 5 inches are now commonly quoted in cc volume.

The Test Engine.

The engine for our tests here was a T&L 383 built in spring 2006 and used extensively as a dyno mule. time it has been used to test cams, rockers, heads and a variety of induction systems. At this point in t about the equivalent of 500 road race miles on it. The bottom end was an all Scat/KB deal. The crank v 9000 series cast steel stroker (3.75 inch) with Scat stroker clearanced rods and KB forged pistons. In o KB's, with the test heads involved, delivered a 9.5/1 CR.

The intent here was to run four pairs of the heads courtesy of Dart on this engine. I say courtesy here project was largely pushed through by Dart's Jack McIness who felt that it would be in the best interest customers to have it demonstrated that bigger in the **port** department is not always better. These hea latest Pro 1 Platinum style, had intake **port** volumes of 180, 200, 215, and 230 cc.



Here is a shot of Darts Platinum heads chambers with and without valves. The design of tl the result of a lot of R&D on both wet and dry flow benches and the dyno. If this technol converted into results on your motor it makes sense to choose the right port volume for th

At this point it may appear what we planning is an easy test to do – just take a strong performing engi sets of heads across it. Unfortunately without a little more thought this is were things can go awry. To results we need to look at things in a little more depth. What can be a major factor toward achieving m results arises from the way flow increases with increasing **valve** lift and **port** volume. At low **valve** lift around 0.050 to about 0.150 the flow has little to do with the **port size** because the limit is set by the through-flow area between the **valve** and the **valve** seat in the head. Only when the **valve** lift exceed of the valves diameter does the **port** size/flow efficiency begin to influence flow as seen on the flow be our test heads is amply demonstrated in Fig 1. From the curves you can see that the majority of the flc

with increasing **port** volume occurs at the higher lift value. This is so to the extent that any test that fa
intake **valve** to access the additional flow would be totally skewed in favor of the smaller **port** heads.

To achieve meaningful results here meant selecting a cam and valve train that combined lift and short duration for a wide power band. These two factors are not quite mutually co this meant having a valve train with good dynamics. Here we selected a custom Comp sir 276 Xtreme roller hydraulic grind.

Another consideration here is that a cam with a relatively short duration would also be needed thus allo speed attributes of the heads to be determined. Using a cam with too much duration would prevent the running decent at low speed so any head volume that favored low speed would look worse than it poss this reason it was felt that the greater lift of a moderated duration roller cam was best suited to the tes involved. To meet these needs Comp ground a custom single pattern Xtreme profile (#3192) shaft on a hydraulic roller profile has 276 degrees of 'off-the-seat' duration and 224 degrees at 0.050 tappet lift. T with a peak lift of 0.605 when paired with a set of 1.6/1 rockers, got the job done.
All the heads to be tested had 72 cc combustion chambers (64 cc ones are also available) which, with t combination of deck height, piston **valve** notches and gasket thickness gave our test engine a 9.5/1 CR opted to test the 64 cc items the CR would have been bumped to 10.7/1.

As for the induction on our mule motor an influential carb and manifold decision had to be made. What had to be able to deliver results at both ends of the rpm range. In other words the validity of any **port** is influenced by the intake manifold and carb selection. Unless high flow capability is seen here the diff cylinder head performance, especially at the top end of the rpm range, will be masked. The intake sele previous positive experience was Dart's 180 degree 2 plane design.

But what was planned here was far from just bolting up the same intake to each set of heads. Rememb has a different **port size** opening at the manifold face. What we want to test here is the effect **port** vo power not what effect **port** matching has. To deal with the **size** differential the 180 cc heads had a sm applied to the intake ports of the heads as the manifold was slightly larger. For the other three sets of manifold runners were opened up over about the first inch in to match the **port size** of each successiv head.

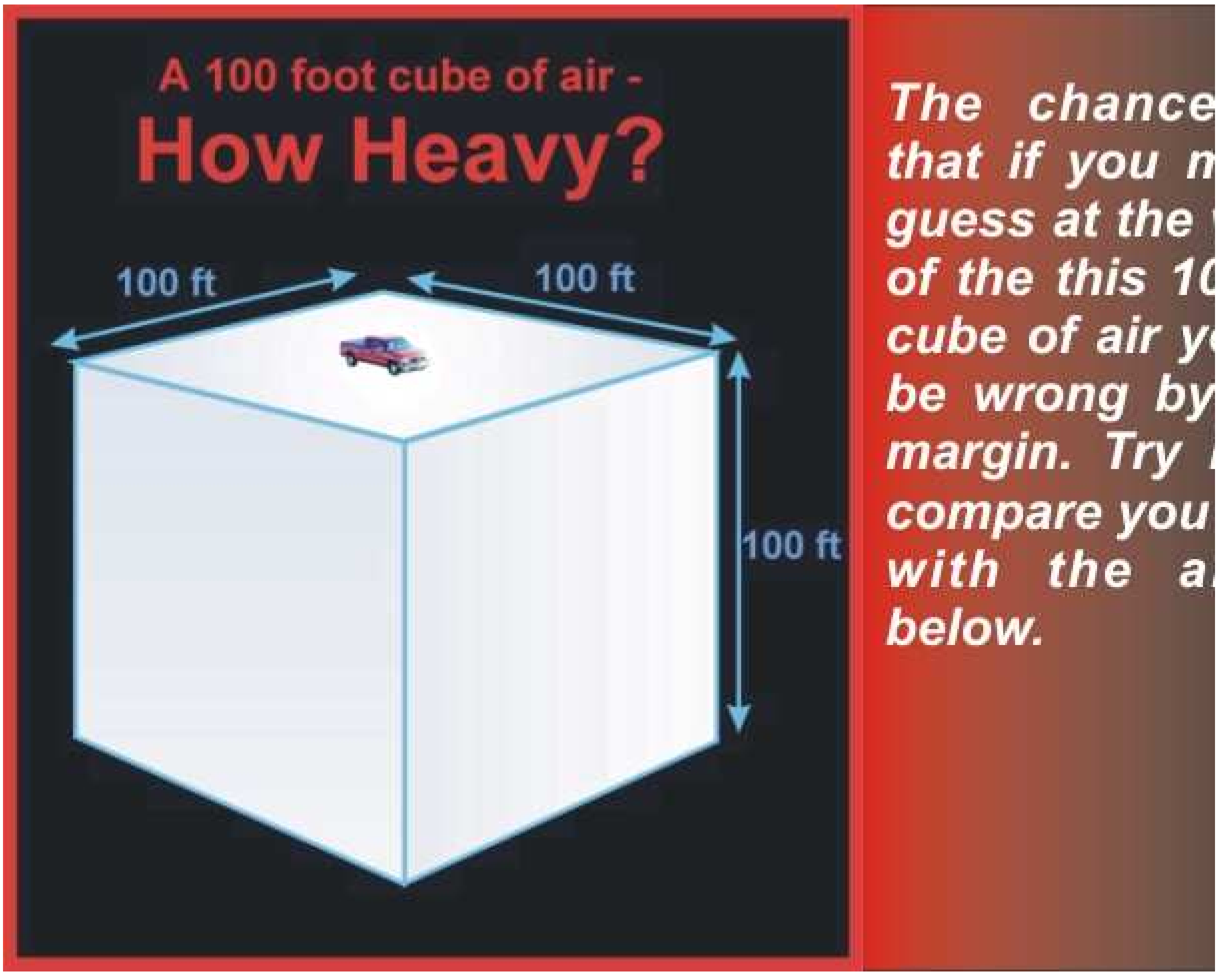
Feeding the fuel to the system was an AED Holley with some 950 cfm flow capability. With this inductio engine had access to sufficient air flow for a good top end while still catering for whatever low speed th **port** heads might deliver.

So you can see where we stand on this let's consider what our alternatives may have delivered. If we h single plane race intake such as a Victor Jnr. or the like, the bigger **port** heads could well have shown end advantage over the smaller ones. On the other hand a race style single plane could have comprom smaller **port** heads ability to deliver a stronger low speed output. Conceptually at least, the induction s proved to be a globally effective compromise.

Port Sizes.

So why is **port** cross sectional area important? If the area is bigger the flow surely goes up and that's v
is it not? Sure the engine wants as much airflow as possible but air has mass and weighs much more th
think. During my lectures I have used the 100 foot cube question on literally thousands of professional
many of high repute and, in I don't know how many years, not one has come close to the right answer
you do any better here.

Imagine a cube with 100 feet down each side – that's 100 feet long, 100 feet wide and 100 ft high Fig
stopping to calculate it, if you happen to know how, guess (assuming standard temperature and pressu
the air is within that 100 foot cube.



**The above drawing shows the scale of what we are dealing with here. That's my GMC Sier
cab truck parked on the 100 foot cube. The chances are you totally underestimated the w
air in that cube. I'll tell you now – the answer is thirty eight (I am writing the number as w
don't immediately spot it). Now that is not thirty eight lbs nor thirty eight kilo's but thirty
Yes it would take no less than 17 GMC Sierra's to balance a set of scales against the weigh
foot cube of air. Now if that surprised you don't feel like the Lone Ranger here as, to dat
people in 20 years have come even close to guessing anywhere near the right ans**

So why am I bringing up the point on the weight of air. It is solely to put into prospective that the med
dealing with is far from near massless. When that air is moving at 600 feet/second it has considerable
Just so you can visualize the amount of energy here is an example. The total intake **port** length of a Pr
at 10,000 rpm has only slightly less energy than the muzzle energy of 0.177 caliber pellet from a reaso
powered air rifle (about 10 ft-lbs).

Shown in the photo on the left are the 180 cc and 230 cc ports for a comparison of the sm the biggest. The illustration on the right shows the difference in the average area of each being tested.

So air is heavy – if we add to this the fact that the energy is equal to half M(mass) times V(velocity) sq (1/2MV^2) we can see that when **port** velocity goes up the **port** energy goes up far faster and when drops the **port** energy drops far faster. Putting that into prospective if a **port** is made 20% too big the drops by 44%. In basic terms that equates to a 44% drop in the ports ability to ram a cylinder by mea velocity derived momentum. When it comes to combating reversion, especially at low speed **port** veloc effective. Kill the velocity below a certain level and you effectively kill torque at the lower rpm levels wh necessarily garnering any power advantages at the top end.

So what we can say at this point is that a significant proportion of an engines flow through depends on as well as the generation and utilization of pressure pulses. This means even a little excess in terms of hurt power even though it may, on the flow bench at least, flow better.

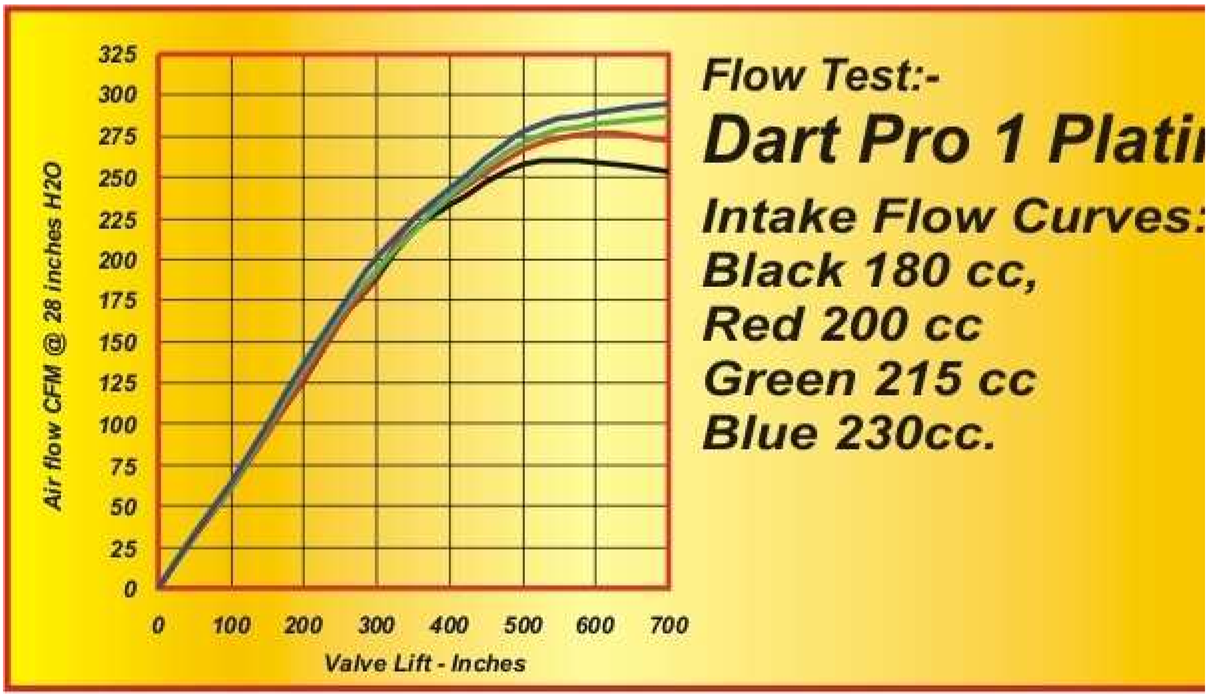


Fig 2. As these curves show big ports do deliver bigger flow numbers but only at high lift. train does not access that lift then the extra port volume is totally detrimental to ou

As can be seen from the flow tests above (Fig2) the bigger **port** does flow more up at the higher **valv** Having established that the big **port** flows the biggest numbers we are now left with the question as to directly translates into extra output or is velocity a sufficiently active player to have an overriding influe results?

Dyno Time.

At this point we have a lot of output data to consider and to make this easier to assimilate I have put t curves and power curves on separate charts. A point worth noting here if you are attempting to convey small differences in torque and hp over an entire power band width of an engine is that it is easier to s differences at the low end by looking at the torque curves but for the top end differences are easier to at the power curves. Now I have made that point let us look at the low speed effects (Fig 3) when the was changed on our test engine.

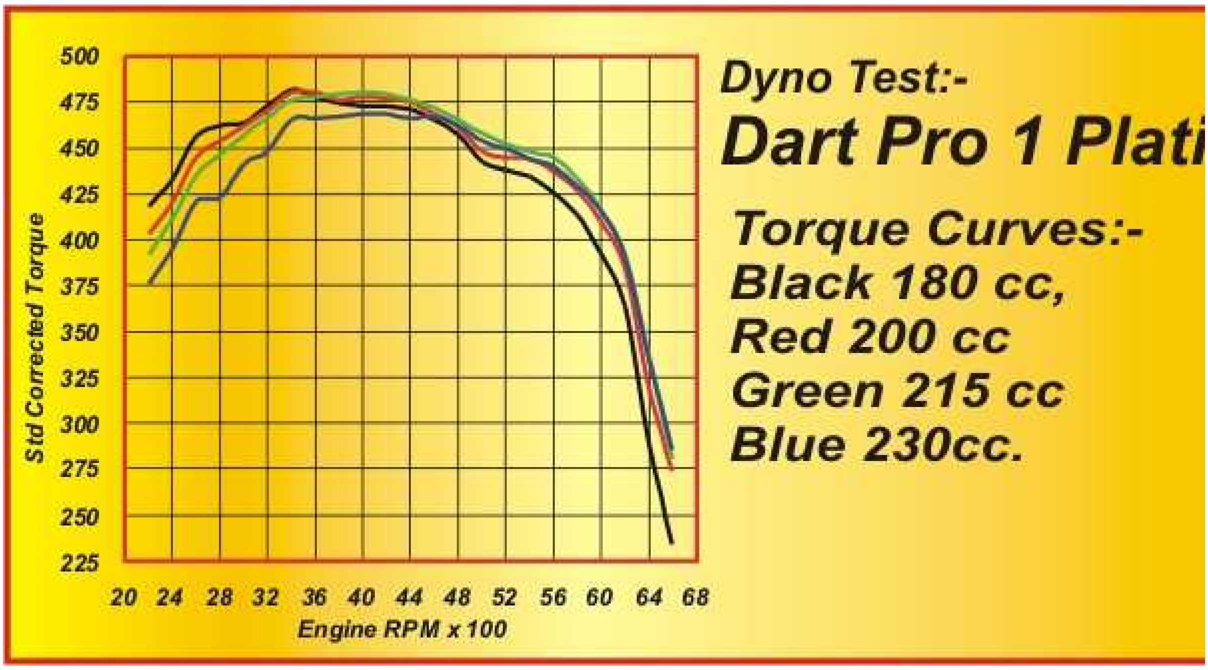


Fig 3. The results here clearly show that smaller, higher velocity ports, favor low speed o results also show that going too big (blue curve of 230 cc port) on the ports, for the jol produces worse results almost everywhere in the rpm range.

As we can see the curves clearly show that smaller, higher velocity ports, strongly favored low speed o clearly produce the best results to 3400 rpm. Above 4500 rpm the 180 cc ports lost out to all of the big configurations. These results also show that going too big (blue curve of 230 cc **port**) on the ports, for hand, produces worse results almost everywhere in the rpm range. The only point at which the 230 cc better on our test engine was above 6200 rpm as shown on the power curve graph. At this rpm the po about all over anyway so any advantage this far up the rpm range would not show any advantage on t What we can say then is a 230 cc **port** – for this application- is simply too big. Since this **port** has the numbers but the lowest velocity we can conclude that it is necessary to get the right compromise betw for best flow and **port** velocity for best momentum filling.

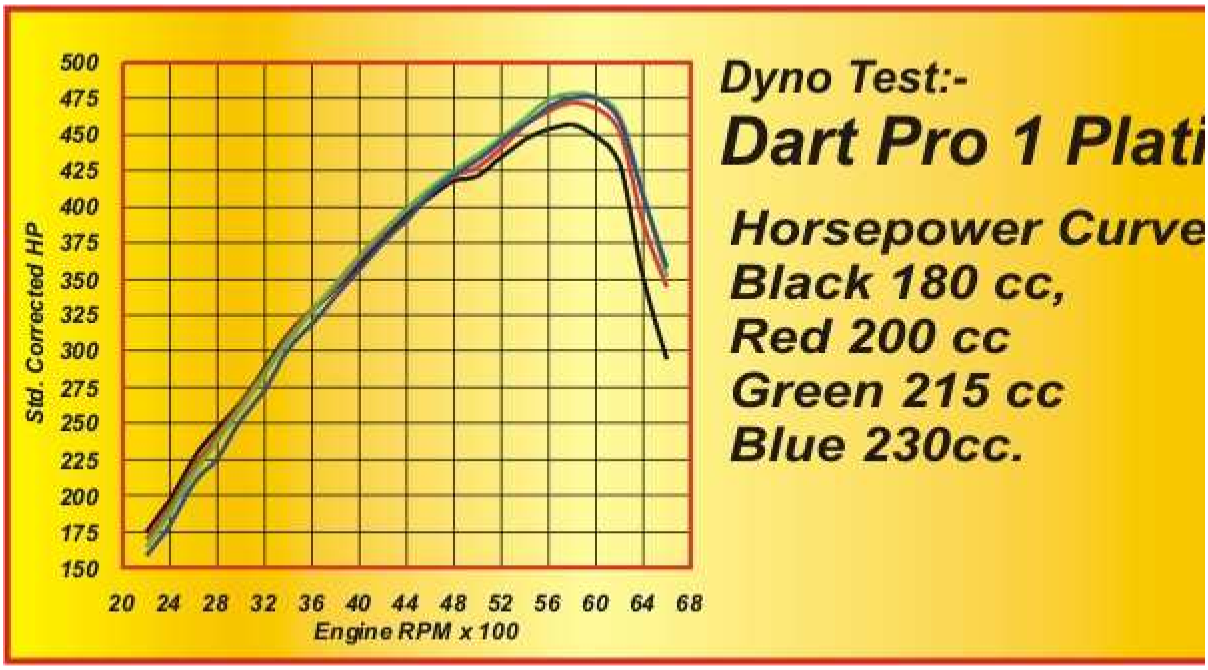


Fig 4 Here it can be seen that the 215 cc port (green curve) equaled or bettered the 230 c

curve) everywhere so proving bigger is not always better. Combining what we see from curves and the hp curves the 200 cc runner (red curve) appears to give the best average n the rpm range tested.

Before finalizing on our conclusions here let's give these results another look. From the torque curves F the 180 cc ports (black curve) produced the best output up to 3400 rpm peaking at a stout 482 lbs-ft. \ see the 200 cc **port** (red curve) was not far behind at the lower rpm and from 3400 rpm up it ran up w too the bigger ports. If we look at the torque curves and also consider the hp curves in Fig 4 we can se 383 incher's cam and intake combination, and the intended rpm range, the 200 cc ports produced the l 215 cc (green curves) heads delivered the highest output at some 478 hp as apposed to 457 for the 18 472 for the 200 and 475 for the 230's. The downside of the 215's over the 200 was that to deliver this they give away up to 10 lbs-ft of torque between 2300 to 3200 rpm.

As for the 230 cc **port** runner heads they failed to deliver any worthwhile superiority anywhere in the r our test engine. Indeed the smaller 215 cc **port** heads beat the 230's everywhere! This, in case it was near conclusive proof that an engine is not a simple air pump! Nor, for that matter, is bigger better. Ha an engine capable of more rpm or one with bigger displacement then the bigger **port** heads would hav Experience with ports in the 230 -245 range show that every bit of the **port size** is needed if you are l cube small block Chevy. If we look at a comparison on a pro-rata basis a 235 cc **port** on a 440 inch sm Chevy is only equivalent to a 186 cc **port** on a 350. A worthwhile point of reference here is that since t of a small block Ford is also very similar to the small block Chevy the results seen here transpose pretty Ford.

So how do you decide what **port** volume your small block should have for best results? As good a rule any is to base the **port** volume, and we are only talking traditional 23 degree (or – in the case of Ford heads here, on the projected power output. However let me caution you that that if you rate your engi output too optimistically(and an excess of optimism is a problem most racers have) you will end up wit is too big and the target output will not be reached. What this means is you could end up sabotaging y efforts here. If you go with the recommendations in the chart Fig 5 you should have a good starting pc volume selection.

Projected HP	Port Vol. Min - Max
350 - 400	140 -160
400 – 450	160 - 180
450 - 500	180 - 200
500 - 550	200 - 220
550 - 600	220 - 230
600 - 700	230 +

Fig 5
This chart gives a good working guideline intake port volumes to target for a small loc Remember a little too small is much bette little too big. If the port volume of the h have seems a little too big go for compression ratio the fuel intended will this will, to some extent, compensate.

With Darts selection of **port** volumes they pretty much have the range from a relatively mild 350 (180 rampant 440 incher (230 cc ports) covered. One more point worth noting for those higher hp engines t these Dart heads are really easy to **port**. Doing so can get the **port** volume right where it needs to be more flow.

Summing Up.

Before winding up this feature there are two points I want to make clear. First that a **port a little too a far better deal to drive than one that is a little too large**. 20 cc extra in a small blocks intake p cost 25 lbs-ft and sometimes as much as 40 lbs-ft at a point in the rpm band that is most often used fc driver. **Also a port that continues to increase in flow at more than say 0.050 above the maxi will be used shows almost conclusively that the port is too big.** That is a real mismatch of **port** cam/valve train spec.

For those of you considering building a small block Chevy a mention on Dart's Pro 1 Platinum heads ou seems in order. Our 383 test mule was later reconfigured with the as-cast 200 cc heads, a 280 degree Hydraulic roller cam and, with a 10.5/1 CR delivered a best pull of 500.3 lbs-ft and 502.1 hp with comp drivability.

David Vizard

Other articles in this series can be found at:

#1 Porting School #1 - Why engines need airflow

#2 Porting School #2 - Super Cheap Flow Bench

#3 Porting School #3 Budget Bench Calibration

#4 Porting School #4 - Budget Bench Electronics

#5 Porting School #5 Identifying Primary Restrictions

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#7 Porting School #7 - Power & Port Volumes

#8 Porting School #8 Optimal Port area's

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#10 Porting School #10 - Pushrod Pinch Point Power Issues

In addition to the Porting School articles there are directly related cylinder development subjects at the following sites:

Wet Flow :-

Six Wet Flow Mistakes

Combustion Dynamics:-

#1:- Turbulence and Combustion Dynamics

#2:- In cylinder Turbulance and Combustion Dynamics

#3:- Turbulance and Combustion Dynamics - Part 3

#4:- Coming soon

#5:- Turbulance and Combustion Dynamics - Crevice Volumes - Stealth Power Thief

Machinists

Last edited by DavidVizard-GFN; 09-18-2008 at 08:13 PM.

07-17-2008, 12:29 PM

#**2** (**permalink**)

1989GTA OFF
Tire Changer

Join Date: Oct 2007
Posts: 112

Thanks David for the excellant article. Personally I would have gone with the 64cc ports and the 10.7:1cr. With the modern design of the Dart head with the double quench pad I feel they would run on 91 octane gasoline with no problems.

QUOTE

07-17-2008, 04:43 PM

#**3** (**permalink**)

DavidVizard-GFN OFF
Pit Crew

Join Date: Apr 2007
Posts: 840

1989GTA,

We ran mostly on 89 octane for 9.5/1 Dart headed motors. On 10/1 -11/1 compression engines we have used premium. I have not tried over 11/1 on the dyno and have not run more than 10.7/1 on the road. I have heard that 11.5/1 can be used when the water temp is kept low (170) on the dyno but I don't know if this would work on the street. Any body got anything to say about that?

DV

QUOTE

07-18-2008, 01:24 PM

#**4** (**permalink**)

automotivebreath OFF
Oil Changer

Join Date: Jul 2007
Location: Southern Louisiana
Posts: 450

I have done extensive experiments with high compression low octane engines. I find that it's very difficult to realize any benefits from an increase in compression over the ratios that David posts ***"89 octane for 9.5/1 Dart headed motors. On 10/1 -11/1 compression engines we have used premium"***. Anything above this normally requires some sort of compromise like lower water temperature, reduced ignition advance,late intake **valve** closing and or richer air/fuel mixtures. Not worth the trouble IMO.

QUOTE

07-18-2008, 01:50 PM

automotivebreath OFF
Oil Changer

Jo
Lo
Po

Quote:

Originally Posted by **DavidVizard-GFN**

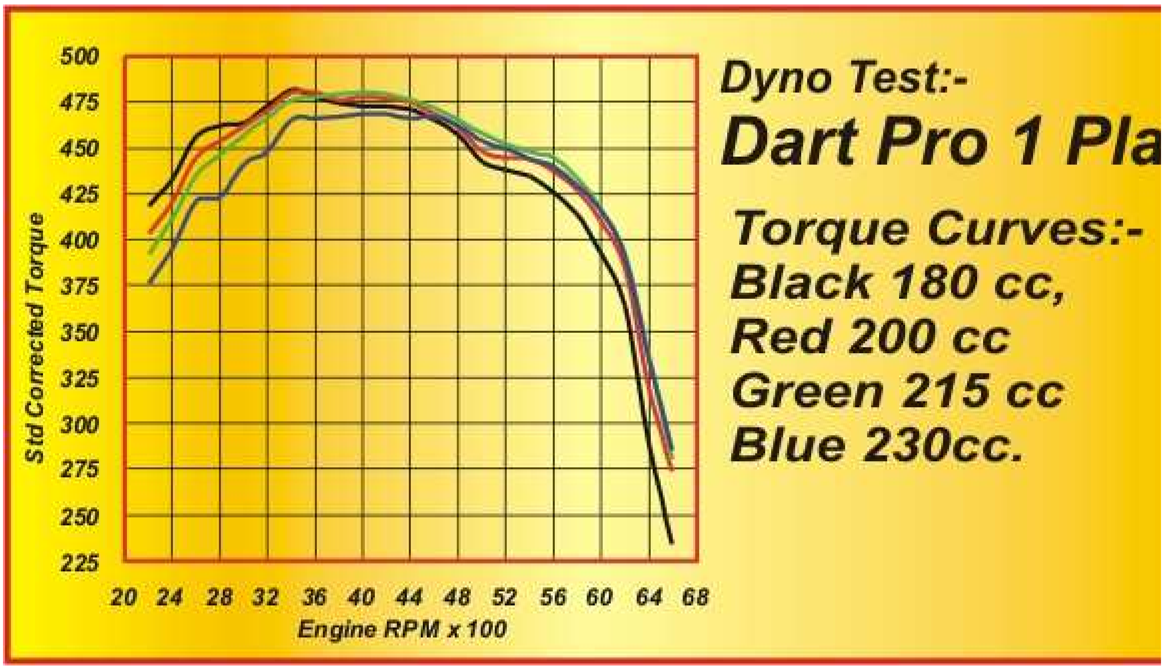

Fig 3. The results here clearly show that smaller, higher velocity ports, favor low spee results also show that going too big (blue curve of 230 cc port) on the ports, for the produces worse results almost everywhere in the rpm range.

Great article David, I have been waiting for this one, oversizing an engines **port** is likely one of the biggest mistakes made. In addition the Dart head was a great choice for the article, clearly the best option for as cast performance.

To build on what was was said by adding a twist; consider taking the 180cc intake runner head and modify the ports removing ~5 -10 cc of material with the goal of to enhancing upper RPM power with out hindering the superior low speed torque.

If we were to match the upper RPM power potential of the 215 cc runner head with out losing the torque displayed between 2400 -3600 RPM we would create the best of both worlds with a seemingly little 185 - 190 cc **port**. It's a win-win situation, especially for the street strip type car.

07-18-2008, 02:05 PM

#**6** (**permalink**)

DavidVizard-GFN OFF
Pit Crew

Join Date: Apr 2007
Posts: 840

AB,

You scored a bulls eye here. We have ported a couple of sets of 180 cc Darts for 350's. They are easy to **port** and produce just the kind of results you are speaking of. With 10.5/1 CR a decent but not expensive flat tappet cam of around 285 degrees seat, a Victor intake 800 cfm of good carburation and you can be looking at 460 lbs-ft and 510 hp for a street driver.
DV

QUOTE

07-18-2008, 03:21 PM #**7** (**permalink**)

old blue 75
Garage Sweeper

Join Date: Mar 2008
Posts: 84

Quote:

> Originally Posted by **DavidVizard-GFN**
> *AB,*
> *You scored a bulls eye here. We have ported a couple of sets of 180 cc Darts for 350's. They are easy to* ***port*** *and produce just the kind of results you are speaking of. With 10.5/1 CR a decent but not expensive flat tappet cam of around 285 degrees seat, a Victor intake 800 cfm of good carburation and you can be looking at 460 lbs-ft and 510 hp for a street driver.*
> *DV*

David have you tried this cambo with a 2 plane intake? If so how do the numbers change.

QUOTE

07-18-2008, 07:28 PM #**8** (**permalink**)

Horsewidower
Garage Sweeper

Join Date: Oct 2007
Location: Wilton Ca
Posts: 15

Boosted Apps.

Maybe you'll get into this on #6, but what, if any, should we take from this for a boosted application? Would it be inaccurate to say that velocity is provided by the boost and therefore a larger **port** volume would not cause the same loss of power and drivability? Provided that you have reached the boost threshold. At what point would you have too big a **port** even for a boosted app, when you've reached the choke limit on the turbo, you have decreased psi, and the hp tops out and begins to decline? Wouldn't I just need to go to a turbo that can produce more mass airflow at that point?

I'm currently running a head that flows 240 cfm and have another one that flows 315 but the ports are ginormous.

I realize that your general audience for these pieces is a NA crowd, but there seems to be a yawning gap in the information available for these basic discussions when it comes to boosted apps. The usual response is, why worry about those things, just turn up the boost.

Thanks in advance:

Bob

QUOTE

07-19-2008, 02:06 AM #9 (permalink)

sir yun OFF
Garage Sweeper

Join Date: Mar 2008
Location: mainland europe
Posts: 13

"Imagine a cube with 100 feet down each side – that's 100 feet long, 100 feet wide and 100 ft high Fig 1. Without stopping to calculate it, if you happen to know how, guess (assuming standard temperature and pressure) how heavy the air is within that 100 foot cube".

the ideal gas law
P x V = n x R x T = g / M x (R x T) or g = (M x P x V) / (R x T)
where R = 0.082, the gas constant. Substituting: P = 1 atm, V = 1 liter, T = 298, M = 28.9, and R = 0.082 gives the weight of air at normal gravity of about 1.2 gm.

hmm according to my calcs a 100ft^3 cube is 28.316 liters*1.2...

that'll be a tad under 34 tons then.

Last edited by sir yun; 07-19-2008 at 02:10 AM.

QUOTE

07-19-2008, 10:39 AM #10 (permalink)

DavidVizard-GFN OFF
Pit Crew

Join Date: Apr 2007
Posts: 840

Sir Yun,

The weight SAE specifies for a cubic foot of air at sea level under standard conditions is 0.076 lbs per cubic foot. That number times one million comes to 76,000 lbs or 38 tons. Water vapor as I remember it is part of this but I have never checked to see what percentage is assumed in a standard sea level cubic foot.

DV

QUOTE

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