

building the hot holden six by snarlyjohn@gmail.com

tips part 2 - for the ~~jaded~~ more experienced

This is another list of random thoughts and general tips, but this time aimed at the builders with more experience. Reading them now it strikes me that most of them have quite a conservative, almost anti-technology tone. But I'm anything but anti-tech; the message I was trying to get across was pragmatism over tech-for-techsake. Some are plainly obvious but it's remarkable how often we ignore the plainly obvious so I included them as a reminder...

1. **Everything is a Spring** - or a tuning fork or maybe an organ pipe. After working with machines for a while you realise that whether you like it or not everything is flexible and has a natural resonant frequency. This applies to damn near everything in an engine: the crank, camshaft, pushrods, valves, the block itself, the gases inside the inlet and exhaust ducting. Never ever ever discount the importance of this - it is one of the fundamentals that determines whether the engine makes power or whether it can even survive at full load and speed without eating itself. At times you'll want to maximise these resonances, at others you'll want to reduce them as much as possible. Or perhaps you'll just want to change the frequency. One way or another, you can count on having to deal with it.
2. **Unmanaged vibration breaks things** - this is a continuation of the previous paragraph and I find it a bit surprising how regularly it's missed. How often have you seen parts break that really should have had ample strength in view of the loads applied? It happens all the time and the usual response is to beef up the part in question - usually over several iterations - until it stops breaking. When a part breaks but it doesn't appear to be overloaded the problem is usually vibration related. Sometimes making the part stronger and heavier solves the problem (more likely through changing the resonant frequency than through increased strength) but just as often it merely changes the speed at which it breaks and/or shifts the problem to another part of the system. Don't discount the importance of vibration - its effects crop up continually and you need to be able to manage them.
3. **Don't underestimate the benefits of continued development** - they nearly always trump "superior" technology. What are the best performing (in terms of specific output) naturally aspirated engines of today? People unfamiliar with racing technology might think of an older n/a F1 engine, a Euro sports car or perhaps a MotoGP engine but there are much simpler engines that equal or exceed the BMEPs of these: NHRA Pro Stockers. These appear antiquated in design - they have just two valves, actuated by pushrods and rockers, carburetors, a distributor, fixed valve timing and run on petrol - but decades of development have enabled these engines to produce remarkable outputs for their cylinder size. Would a more modern design make more power given the same amount of development? Certainly. But for someone wanting to win races within a realistic timeframe a modern but less-developed engine could well be a foolish choice.

In a similar vein the humble Holden six has pleasantly surprised me in recent times. When I first wrote the introduction to this site I warned the reader not to expect too much from the little motor. But outputs have climbed slowly but steadily since then and N/A outputs of around 2hp/cube are now becoming more common with factory heads, 1.5hp/cube being quite streetable. In Group NC the XU1s more often than not embarrass the V8s and 911s. All this comes not from any revolutionary techniques; just steady incremental development from a handful of industrious men.

4. **Innovation is essential** - but be careful you don't end up with neither money nor trophies. Obviously, without innovation we'd still be racing donkey carts. And one of the things many of us find so attractive about motor sport is the technical aspect, especially the innovation. But you have to be pragmatic about it. Unless you have enough money to run an R&D; program in parallel to your normal operations then maybe it makes more sense to let someone else do the innovating. While they develop the next big thing you can be winning races and retaining your sponsors. True, there is the occasional leap forward that just works from the start, but for every Cosworth DFV I'll bet there are a hundred ideas that never make it

past the money-pit stage. It's a tough decision for sure - innovation and R&D; is interesting, stimulating, fun - but if consistent results are the goal then just maybe piggybacking on the back of someone else's hard work may make more sense.

5. **Don't ever get the idea that automotive technology is in the slightest bit advanced** - or that exposure to other spheres of technology is unimportant. Nothing could be further from the truth - racing technology isn't at all cutting edge and the industry tends towards parochialism. Machinery and technology is everywhere, not just in cars, and you need to be paying attention to what the rest of the world is doing. The ability to build 1000hp race engines doesn't necessarily imply any particular expertise or understanding - these days anyone with a toolbox and a Summit catalogue can do it. Be particularly wary of single-marque specialists - I'm occasionally surprised by the ignorance (if not outright stupidity) of some of these guys.
6. **Expediency isn't a dirty word - and good enough really is good enough.** And if it isn't it never was. Simple eh? There are two things that are always in short supply - time and money. Don't make anything better than it has to be if to do so requires more of either. I'm not saying you shouldn't apply every bit of attention to your engine build that it requires, just that you should recognize when something is good enough so you can move onto the next item on your list. The amount of time wasted on things that are already good enough is staggering - check the web forums for tragi-comic proof.
7. **Pay attention to what the OEM engineers are doing** - their job gets harder every day yet they still churn out some amazing stuff. Once upon a time it was claimed that racing improved the breed and that racing developments sometimes made their way onto production machines. I'm not sure if this was ever true but for a long time now the technology flow has been in the other direction. In recent decades massive improvements have been made in managing combustion efficiency, friction and ignition performance, all stimulated by the need for OEMs to meet mileage, performance and emissions requirements. These have flowed on to the racing world as well. There are some beautiful engines out there - Ford's Barra and Coyote, the GM LS series, and some of the Toyota and BMW sixes come to mind - and no matter what your engine of choice may be you should keep an eye on what these guys are doing.
8. **Technology can be subtle** - just because it isn't always obvious doesn't mean it isn't there - newbies are particularly susceptible to missing the subtle stuff. An example: Top Fuel cars are the fastest accelerating cars in the world - the record being around 3.7 seconds at nearly 330mph. These are very simple cars with a steel tube frame and I'm pretty sure I could knock up a virtually identical frame in a few days. I'm also sure that my frame, while looking much the same, would completely fail to hook up, would be dangerously unstable and most likely encourage violent tyre shake. What's the difference between mine and the ones that the handful of four-second-and-under fabricators make? The underlying physics and resulting technology. It mightn't be obvious but the builders of the fast cars understand it intimately.

Another example is GM's brilliant LS series. Anyone unfamiliar with them could be forgiven for having low expectations - say 1.5hp per cube - after all they're just another pushrod V8, right? What you can't see though are the exceptional breathing and burning characteristics, and these are what allow these engines to make remarkable power with nothing more than a little more area under the lift curve. Again, the technology is there, it just isn't obvious. And I guess the flip side to this is don't mistake "technology" for the real thing. There have been quite a few engines produced that looked impressive to the novice - all alloy, multi-cam, multi valve etc. - that turned out to be dogs. Real technology impresses with a timeslip or a dyno report.

9. **If you want to know which way to go** you first need to look at where we are now and how we got here. Looking back has benefits. For a start it can be very enjoyable and entertaining to read about the work of Ricardo, Lanchester, Goosen, Irving, Morrison, Blair et al. And you avoid duplicating their work needlessly. Every young man with an interest in engines wants to set the world on fire with a supercharged, twin-crank engine with opposed pistons sharing a common chamber, not realizing it's been done already umpteen times and encountering the same pitfalls every time. Same goes for any number of dodgy rotary valves and displacers. It's all been done. Reading the old timer's stories gives you a feel for what's important and what isn't, not just in engine design but in your own personal approach. Unfortunately it appears that there is no substitute for plain old persistence and sheer hard work, no matter how brilliant one may be. Dammit.

The biggest benefit of looking back is being able to see the patterns emerging over decades of engine development. Funnily enough most of the OEMs followed much the same path, whether US based, Japanese or European. And it seems that the path they followed was dictated by trial and error as much as anything else. The biggest and most meaningful evolution was in head design, and it seems that the design of the chamber in particular is about the only hard limit on an engines potential - everything else can usually be worked around to some extent.

Ignoring the old sidevalve engines, most of the early OHV engines had inline valves and a wide variety of chamber shapes were tried - some simple, some downright weird. At some point hemispherical chambers became fashionable and nearly everyone produced a range of hemi engines. For a while the breathing advantages of the hemi outweighed its very poor combustion characteristics but it eventually became apparent that it really only worked well in boosted applications or with a very small bore size. Some burned so badly that twin plugs were needed and besides, they were bulky and expensive to produce so the OEMs went back to inline valves. Despite its problems the hemi did achieve remarkable success in supercharged drag racing and on the longer ovals like Daytona and Talladega. This is where the hemi gained its legendary status and even today Chrysler uses the hemi name as a marketing tool for some of their modern engines that aren't really hemis at all.

The inline-valve successors (using contemporary heart shaped or wedge chambers) with better developed ports generally outperformed the hemis, even if the outright flow was somewhat diminished. In the 50s and 60s Chrysler went to the shallower chambered polyspherical A series, and canted valve engines like the Clevo and BBC were developed in an attempt to achieve hemi-like breathing but without the bulk and expense of the hemi valvetrain. For a while these engines were top of the heap and even today there are some good aftermarket examples. But generally the chambers suffer from being too deep when compared with today's state of the art.

So what is today's state of the art? We've come full circle back to inline valves with a very small (or zero) inclination angle. Modern designs like the LS have a shallow chamber with a very fast burn, and with intake ports flowing 350cfm or more the old engines are left behind. Similarly, four-valve engines have evolved in the same way with all current engines utilising a very shallow chamber and a very small included valve angle.

Why this spiel on head design in a page of tips? I wanted to show just how much you can learn about engine design simply by being aware of its evolution. As Henry Ford said, the further you go back the further you can see ahead.

10. **Some engine components help make more power, others just prevent losses** - or in other words some actively increase the output while others just help prevent bad things happening. Silly semantics? Possibly. And what the hell does it matter anyway if the end result is the same, ie. more power? Well, I think there really is a difference and I think the distinction matters. Here's why: a component or a process that makes power is essentially of unlimited potential. Keep developing that part or process and the output will keep climbing. On the other hand activities that help by reducing the effects of negatives have limited potential. Examples: every time you improve the bulk flow into the cylinder you'll increase output. But increasing output by reducing something like reversion is a finite exercise, once you've eliminated it altogether there's no more power to gain. So should you really spend 50 hours on the flow bench trying to get rid of that last little bit of reverse flow? Or would you be better off spending that time on intake manifold design? This is why I think recognizing the distinction matters; it can help prevent you from wasting time on things that can make limited contributions and distract you from the things that really matter.

Some examples of things that actively make power - head flow and flow quality, camshaft and valves, mixture motion, intake manifold design. These are the things that for all practical purposes have limitless potential. Examples of things that work by reducing the incidence of bad events and effects would include carbs and injectors (they can't make more power, only recover that lost to poor distribution etc), exhaust system design, scavenging, friction control, fancy ignitions etc. I know many will disagree with my including the exhaust in this lot but I really do think there's only so much the pipework can do on a four-stroke. It's still important stuff of course and worth your attention but also worth keeping in perspective.

Despite the limitations many enthusiasts love the stuff in the second group and will spend thousands on ignition boxes, headers, carbs and ECUs. You can't blame them I guess; it's all easily bolted on, shiny and highly visible in the engine bay and it gives them something to do on a Saturday arvo. But they'd find much more power if they'd spent the time where it really matters.

11. **Engines aren't self-aware** - they don't know whose name is on the valve covers, they don't care if they have pushrods or distributors or a prancing horse cast into the engine cover. Only silly humans care about those. In fact there are only a handful of factors that an engine is really fussy about: bulk flow, air density, finite wave management and combustion efficiency being the main ones. It cares not at all for exotic valvetrains; it just wants air. Nor does it want technology for its own sake, again it's only us foolish humans that are impressed by that. It just needs what it needs - give it that and forget the rest. For decades people have been trying to build better Top Fuel engines with quad cams, four or five valve heads and god-only-knows what else. At times they tried more sophisticated European style engines. But still the pushrod two-valve hemi-based V8 is unchallenged. Why? It's Good Enough to make as much power as can be put to the track (currently over

1000hp per cylinder) and strong enough to contain it. More advanced designs look impressive in the pits but the truth is in the timeslips.

12. **Look closely at anomalies** - usually these are rich in clues about how things work. If scavenging is so important then why do four-valve engines care so little about overlap? Why do some engines like a fine fog of fuel yet others like a solid string? Why does a particular engine want a weirdly shaped advance curve? Why was the car quicker when the valvesprings were dying? Anomalies, weird stuff and other oddities offer great learning opportunities that you won't find normally.
13. **More power isn't always the right answer** - even for a drag racer. It won't fix a lack of traction or driving talent, or poor suspension, handling or brakes for that matter. It won't make an overweight car lighter or a fragile car more reliable. And if an increase in power comes at the cost of driveability then it's entirely possible that the car will run slower. The temptation to try to overcome everything with ever quicker acceleration is strong, but really you have to take a long, honest look at the weak areas of both car and driver. Put your time and money where it will do the most good - many races have been won by cars with less peak power than their rivals, simply because they had better traction/driveability/handling.
14. **A picture is worth a thousand words** - or ten thousand if it's a CFD diagram. Airflow is the foundation of any engine so if you don't understand it your chances of success are greatly reduced. Study every CFD diagram you can get your hands on, it'll increase your understanding of how air behaves. And if bulk flow is the foundation stone then pressure wave activity is the um, other very important bit. Animated CFD gifs show more about finite pressure wave behaviour in a few seconds than hours of reading text and equations. Anyway, if you have the time and money for the software you'll be ahead of those who don't. But even if you don't there are plenty of examples online and each one tells a story.

[Previous Page - tips for beginners](#)

[Table of Contents](#)



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