Selecting Boost for the Porsche 928

By Carl Fausett

Set Design Requirements

Before we begin, these are the design requirements that we laid out for our 928 supercharger kits.

1) **There had to be no sign that this is a supercharged car.** We wanted a complete stealth installation by both sight and sound. Nothing to detract from the Porsche 928. No holes, loud noises, or whining.
2) **The price had to be reasonable.** The supercharger kit shouldn't cost more than what was paid for the car.
3) **It had to be able to be installed by a regular person, in a weekend.** If a fellow could change his own oil and maintain his lawnmower, then he should be able to install this kit.
4) **Do no harm to the car or motor.** Damage caused by detonation, disassembly, or modification is not allowed.
5) **Bolt-on Kit.** The Supercharger should be integrated into the Fuel System, but engine disassembly to install the kit should not be necessary.
6) **The kit should be easily removable so you can return the car to stock.** Which may be necessary as often as once every 2 years for emissions testing in some states.
7) **The air conditioner must remain and function.**

Why we selected the supercharger we did

I'm asked sometimes why we selected a Centrifugal Supercharger.

There are three main styles of superchargers, a) Centrifugal b) Paddle (like Roots) and 3) Screw (like Whipple). There are actually more, but these 3 designs are dominant.

All superchargers are measured and compared to each other on many levels – but a main key is “adiabatic efficiency”. That is: the ability to compress the air without heating it. Because hot air expands – heating it while you are compressing it is kind of working against yourself. Our goal is a *dense* charge, not just pressure. We want to increase the air *mass*. Some blower designs are better at this than others.

For example, the Roots/GMC blower… that big impressive beast sticking out of the hood of your drag racing hot rod – will move the most air at the bottom end than any other type because it is a paddle-type "positive displacement" blower. But, it has the worst adiabatic efficiency (about 50%) because it heats the air so much.

Twin-screws can have as good as 65% adiabatic efficiency. Centrifugal superchargers have the best adiabatic efficiency, usually around 75%.

All superchargers, (and Turbochargers too, for that matter) will do the job of compressing the air, but there are some particular reasons why several of them did not fit our design goals.

In the case of the Roots and Twin-Screw superchargers, the intercooler is often placed in the valley of the V8, below the twin-screw; between it and the motor.

That limits how large the intercooler can be, and this design also must fight heat gain by conduction and convection in that hot spot. That is why the drag racers often have their positive-displacement blowers sticking up out of their hood. Check the intercooler under their Roots or Twin-Screw blowers, they are often 8" or more thick!

When I see intercoolers fitted within the V of a Porsche 928 to hold a twin-screw, it is not based on “what’s optimum” but instead done by “what we can make fit”.

Centrifugals do not need as big of an intercooler, and we can place it anywhere so we have room for a bigger one than we need. Also, they are mounted out away from the motor in a relatively cooler environment.

Additionally – the Twin-screw and the Roots style blowers require that you replace your current intake manifold that has tuned-length individual runners with a big open box-type manifold with no or very short intake runners. The loss of the individual tuned-length runners will reduce the range of the engine’s power band and can actually harm the engine.

Here’s why: Intake Manifold design involves the size of the intake runners in diameter, their shape, their length, and the size and location of the plenum and its entryway. It is an involved science whose goal is to generate (in a street-driven automobile) a long and enjoyable power band.

This stuff is not knew – from Vic Edelbrock to Smokey Yunick – you can grab dozens of books that describe how short intake runners benefit one end of the RPM spectrum as long runners benefit the other.

Like most premium automobile manufacturers – Porsche uses un-even length primaries in order to extend the power band as far as it can. If all the intake runners were the same length, the engine would have a very narrow power band in only one tight RPM range. This is unacceptable for most applications. So, they’ll design a pair of primaries that are tuned to pull best at 2,000 to 3,000 RPM, a pair that is designed to pull best from 3,000 to 4,000 RPM, and so on – to develop the drive characteristics that you desire.

Example: The 16v Porsche 928. Two of the intake runners are 38.6 cm long. Two are 37.8 cm long, two are 35.7 cm and two are 35.3 cm.   You do not have to take my word for it. Go out to your garage and pop the hood on your 16v 928. Look specifically at the intake runners for cylinders 1, 3, 6 and 8. Why are those extra bends in there? Because the engineers knew precisely the length those runners needed to be to contribute to the power band where they needed it.

There is no doubt that a big open box manifold would be a lot less expensive to manufacture – so there must be a good reason that I never see one on a production Ferrari, Porsche, Lambo, Chevy, Ford, etc. And we know what that reason is.

The 32v manifolds are no different – it's just that the individual intake runners on the 16v motor are much easier to see from the outside in order to make my point. The 32v intake manifolds are beautifully tweaked and tuned inside – take the side covers off and see for yourself.

Removing the individual intake runners to install a box-style manifold causes problems.

Plenum problems: Plenums are designed to the 10th of a Liter to have the exact volume the manufacturer desires for the best throttle response and yet highest peak HP. A Plenum that is too large will provide maximum peak HP, but washy throttle response in the lower and mid range, and will "Push" (not decelerate) when you lift off the throttle. A plenum too small will have a lower peak HP capability (starving some cylinders at WOT), but will have sharp throttle response. The best volume for a given engine is decided at the flow bench and engine dyno. The engineers design the plenum volume to exhibit the proper resonance at the right RPM's, and get you the best performance for your fuel dollar.

When I see plenums modified for the Porsche 928 to hold a twin-screw, it is not based on "what's optimum" but instead done by "what we can make fit". I have yet to see a kit manufacturer run their twin-screw manifold through the flow bench to see what they have done. I suspect – if they would – they will discover that the placement of the intercooler within the plenum has severely reduced the volume of the plenum, and they may damage the motor at WOT with starvation causing detonation.

Control of Intake Pressure Waves: As the air rushes to your intake valve, it has a certain mass and of course, momentum. Suddenly that intake valve slams shut and a shock wave – called a pressure wave – is caused by the charge air crashing into the back of the closed valve and bounced backwards up towards the plenum.

That pressure wave, if not tuned out or taken advantage of, can literally prevent that cylinder from getting enough charged air the next time that valve opens.

Boosting does not overcome these pressure waves (a common misconception) – it magnifies them.

This is why the tops of intake runners are tulip or bell-mouthed, and why each individual intake valve has its own runner, separate from the other intake runners – so the pressure wave created in valve A does not harm air flow to valve B, and so on. Even just the shape of the bell at the top of the runner has profound effects on how well the cylinder fills and at what RPM ranges.

It is interesting to note that the term used for this phenomenon within engineering textbooks is "natural supercharging".

The Powerplant Engineer turns the pressure wave back around by the size and shape of the bell at the opposite end (the plenum end) of the intake runner. The bell causes the pressure wave to cross sides and start back down.

If they can adjust the length of the intake runners just right - they achieve "natural supercharging". The pressure wave rolls into the back of the valve just as it opens, and a larger than ambient charge enters the combustion chamber. This is so important that Ferrari has actually created variable-length intake runners which vary linearly with engine RPM (done with actuators). An incredible engineering feet all by itself.

Note I did not say "larger than atmospheric" .... I said "larger than ambient" - if there is 5 psi in the pipe.... and you tune the intake runner correctly (as Porsche has) you still benefit from the pressure wave helping you fill the cylinder over and above the boost alone.

The Porsche 928 further amplifies the need for individual intake runners because of their peculiar firing order, firing two cylinders on the same bank in succession. Look at the firing order that the 928 has; 1-3-7-2-6-5-4-8, all the cylinders are nicely staggered away from each other until we get to #6 and #5.

Here, we fire 2 cylinders back-to-back that are right next to each other. If you have an open box manifold with no intake runners, the pressure wave coming out of the head for cylinder number 5 will interfere with cylinder number 6 getting the correct charge. The results will be some cylinders that run too rich at certain RPM’s and yet run too lean at a slightly different RPM. A tuning nightmare.

The motor with no intake runners and a massive box plenum may appear to do very well at WOT but, in fact, even then some cylinders will be too lean while neighboring cylinders will be too rich. The lean cylinders will be prone to detonation and piston damage. Unfortunately, the O2 sensor installed in the collector will not show the problem as it is measuring combined gas temps from all 4 runners at that point.

Another consideration in Supercharger selection: **Emissions testing.**

In states/counties that only do sniff (sampling) tests without a visual test, the centrifugal is more likely to pass emissions because the centrifugal comes in at about 3000 RPM and the emissions tests are done at 2500 RPM (called a cruise test) and at idle. Because the boost has not come in, and the factory Porsche induction/fuel system is still intact, this car will pass emissions – why wouldn't it? At 2500 RPM, it's still all stock.

Not so the Twin-Screw. It will have boost at 2500 RPM, so it will have (if properly tuned) richened the mixture accordingly, and therefore is likely to have high HC emissions if tuned for HP and to avoid detonation.

In States with visual inspections in addition to Sniff testing (California for example): The centrifugal supercharger is an add-on to the front of the motor – it comes off – all the stock manifolds and fuel system is there – go get it inspected, get certified, and come back home and hang your supercharger once again. Easy. To do the same with a Twin-Screw it means you will tear down your motor to the block – removing and reinstalling your complete intake system and all injectors and fuel lines just so you can go get inspected. No fun.

One final consideration for us was the gearing of the Porsche 928. Where the Roots and Twin-Screw make more boost at idle and under 2500 RPM – our design target was to bring in the power from 3,000 to 6,000 RPM for the gearing we have.

Take your 928 right now and run it from 5 to 75 MPH. The Tach and the seat of your pants is all you need to know that the Porsche engineers designed the drive-train and the motor to pull hardest from 3500 to 6000 RPM, and to get best fuel economy under 3000 RPM (like when you have the cruise control set). So we designed a supercharger system that would produce boost in the matching RPM band, and not produce boost when on cruise control at 65 MPH and the engine is loping along at 2200 RPM. Perfect harmony with Stuttgart engineering.

To change that by adding boost at idle speed and the bottom end, is to require enrichment of the air/fuel mixture at all times – even when you do not have your foot in it – producing boost and wasting fuel when you do not need it nor want it. And you are adding torque to the drive-train components at a rate and time when they were not designed for it. Short drive-train component life may be the result.

In Summary: the centrifugal superchargers we use allow us to retain the Porsche individual tuned-length intake runners and plenum in its entirety, and provide us the ability to have a larger intercooler to prevent detonation (and engine damage). They produce their boost in harmony to the 928 gearing and Porsche design, are easier to install, do not require any engine disassembly, and easier to dismount from the car should that be necessary for emissions recertification.