SUPERCHARGERS

COMMON TERMS

Source: www.grapeaperacing.com

CHARGE-AIR-COOLER

Also known as an intercooler and is nothing more than a heat exchanger. When a supercharger compresses intake air it also heats it. Hot intake air is not good for power and will increase the chance of detonation. A charge-air-cooler reduces the intake temperature; it absorbs some of the heat out of the charge. With less heat, you'll need less boost pressure to get the desired power and decrease the chance of detonation. Anything that reduces the intake temperature is a big plus in a supercharged engine

BOOST

Usually measured in pounds per square inch, it is the pressure the supercharger makes in the intake manifold. One of the ways to increase airflow through a passage is to increase the pressure differential across the passage. By boosting the intake manifold pressure, airflow into the engine will increase, making more power potential.

BLOW-THROUGH SYSTEM

This is where the blower is situated before the carburetor or throttle body. The blower compresses only air; there is no fuel until after the blower. Centrifugal blowers are usually set up in a blow-through configuration.

DRAW-THROUGH SYSTEM

This is when the blower is situated after the carburetor or throttle body. In a draw-through system, fuel passes through the blower as well as air. Carburetor sizing and selection is much more critical. An example of a draw through system would be the roots style blowers that are often seen with a pair of carburetors on top of them.

CENTRIFUGAL

Centrifugal blowers rely on the centrifugal force of the air to make compression. They do not displace a given amount of are per revolution like a positive displacement compressor. The amount of air they flow is very dependant on the rpm of the compressor. Centrifugal blowers generally have a higher adiabatic efficiency compared to most positive displacement blowers, but the favor goes toward the positive displacement compressor if low rpm boost is needed.

POSITIVE DISPLACEMENT

If a supercharger is a positive displacement compressor, it simply means it displaces a certain amount of air per revolution, assuming that it is 100% efficient. Roots, vain and screws are all examples of positive displacement compressors. Centrifugal blowers rely on the inertia of the air to make boost, so the efficiency increases as rpm rises, therefore they are not positive displacement compressors.

WATER INJECTION

Detonation can be a problem when running under boost. Water injection is one of the ways to absorb heat and raise the detonation threshold. Under high boost conditions, water is sprayed into the intake manifold. The water does reduce power because it absorbs heat (and the whole idea of an engine is to make heat in order to change it into mechanical energy), but it allows more boost to be run before detonation becomes a problem.

UNDER / OVERDRIVEN

In order to get the desired boost it may be necessary to drive the blower at a speed faster or slower than crankshaft speed. If the blower turns the same speed as the motor it is driven 1:1. If it's geared to turn faster for more or quicker boost, it is overdriven. If it's set up to run slower than the engine, it is under driven.

ADIABATIC EFFICIENCY

A 100% adiabatic efficiency means that there is no gain or loss of heat during compression. A temperature rise equal to the amount of work required to compress the charge would be 100% adiabatic efficient. Most centrifugal superchargers will have around a 60-65% adiabatic efficiency at higher rpm.

Roots Blowers usually fall a little under 50%, some as low as 40%. Roots blowers, like the old GMC's, are very inefficient compressors. Their main advantage is their ability to provide instant boost at very low rpm. That advantage is only helpful if there is adequate traction to make use of that low-end boost. If traction is limited, more low-end power will aggravate the situation. In that case the softer hit of a centrifugal blower may be an advantage.

VOLUMETRIC EFFICIENCY

Compressors are not perfect; there is air leakage around seals, rotors and other parts within the blower. The Volumetric efficiency tells you how much a positive displacement blower leaks. If a 100 cubic inch blower displaces 97 cubic inches per revolution, it has a 97% volumetric efficiency.

MECHANICAL EFFICIENCY

The mechanical efficiency of a supercharger is a measurement of how much power it takes to drive the blower to make a certain amount of boost compared to how much power it would take to make the same boost with no frictional, or other losses.

DENSITY RATIO

Superchargers compress the air to make it denser, this is what allows more oxygen in the engine and give the potential to make more power. The density of the inlet air compared to the density of the outlet air is the density ratio.

PRESSURE RATIO

This is the inlet pressure compared to the outlet pressure of the turbocharger's compressor. For single stage turbo's, the inlet pressure will usually be atmospheric (14.7 psi) and the outlet will be atmospheric + boost pressure. The inlet pressure can be, and usually is slightly below atmospheric. This is due to any restriction in the air cleaner and intake plumbing up to the turbo.

For staged turbo's the inlet pressure will be the outlet pressure of the turbo before it + atmospheric, and the outlet will be inlet pressure + additional boost from that turbo. Staged turbo's are common in high boost applications like tractor pulling engines.

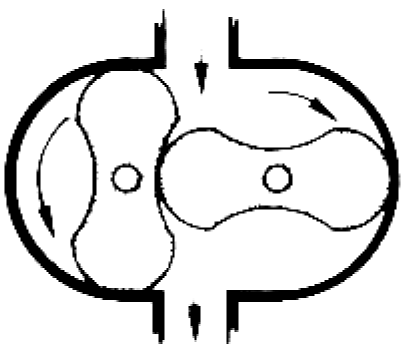
Source: www.grapeaperacing.com

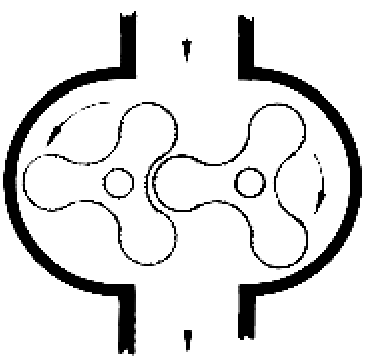
COMMON TYPES OF SUPERCHARGERS

Source: www.grapeaperacing.com

ROOTS (THE POPULAR GMC)

The most popular type of blower used today is the Roots. They are a positive displacement blower. The operation is simple; there is a pair of rotor assemblies turning opposite direction. The air is pushed around the outside of the case and out the bottom. It cannot go back up through the rotors, because there is a very close clearance where the rotors mesh (see figures).

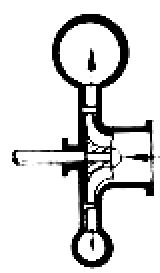


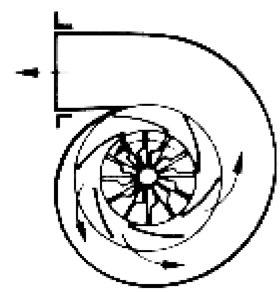


There are usually 2 or 3 lobed rotors, but there have been some made with 4 and 5 lobes in an attempt to reduce intake pressure pulsing. The more lobes there are the less intake pulsing there will be. To further reduce intake pulsing many roots rotors are made twisted. The Roots blowers were originally made to push air (and only air) into 2 stroke diesel engines. The terms 6-71, 8-71, 10-71 etc. are commonly used to describe them, but many people do not know what those numbers mean. The first number stands for number of cylinders and the second stands for cubic inches. A 6-71 blower was meant to be on a 6-cylinder diesel where each cylinder displaced 71 cubic inches. The roots blowers are the most popular because the aftermarket supports them so much, even though the have poor adiabatic efficiency. You can buy a kit to install a GMC Roots blower on to just about any popular engine. Roots blowers are easiest to adapt as a draw through configuration.

CENTRIFUGAL

Unlike the Roots style blowers, a centrifugal blower is not a positive displacement blower. At low rpm, even though it is turning, it cannot make boost. This type of blower relies on the centrifugal force of the air to make compression. As the air comes in at the center of the compressor blades, it is forced outward toward edges of the compressor blades, a snail shell shaped housing directs the air in one direction and slows it down without turbulence (making it denser). The inertia of the air keeps it moving and when it's restricted the pressure builds.



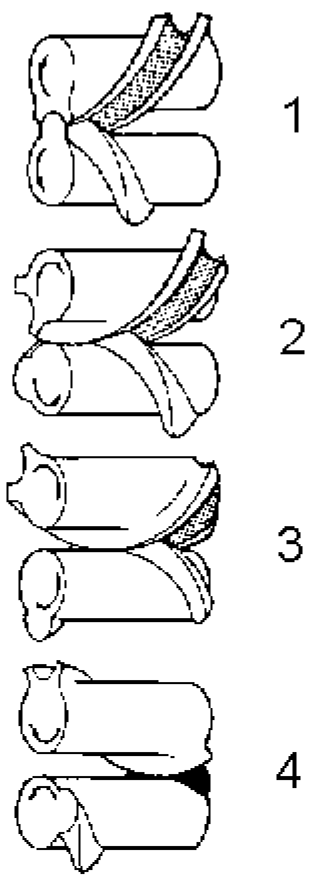


A centrifugal compressor needs rpm to make compression, boost falls off rapidly as rpm decreases. The compressor side works on the exact same principle as a turbocharger, only it's driven from a belt instead of an exhaust driven turbine. The centrifugal supercharger is more compact than the roots type and makes it much easier to use them in under the hood applications. They also work best as a blow through design.

SCREW

Externally, screw type superchargers look much like roots blowers, but they compress air in a very different way. Screw type compressors have two rotors, but unlike a roots blower, one rotor has convex lobs and the other has larger concave lobes (a male and a female). The rotors take air from one end of the case and exhaust it out the other end of the case, again differing from a roots which pulls air from the top to the bottom. As the rotors turn the male rotor fits inside the female rotor and pushes any air toward the exhaust side of the case.

The diagram shows a simplified view of how the male and female rotors work together. The simple drawing shows only one lobe per rotor, but actual screw compressors will have at least 3 or more. There are a few variations; most will have one rotor larger than the other, which could be the male or female.

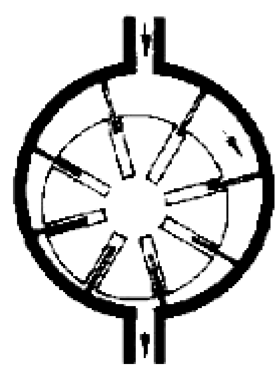


The screw compressor also compresses air within the case; the exhaust side is open to the rotors. It is a positive displacement pump with internal compression and no contacting parts (other than the drive gears), so it needs no internal lubrication. All these things make for a very good adiabatic and volumetric efficiency.

Screw type compressors are more expensive to make, so they are not very popular on street engines, but are getting more and more popular as prices are coming down. At low boost levels, 15 psi and under, it is not worth the extra expense over a roots supercharger. At high boost levels it's efficiency really begins to pay off, making it the better choice. Another benefit is that it has little to no intake pulsing. It compresses very smoothly, unlike most roots type compressors. The screw type compressor combines many of the advantages of a vane and roots type compressors, without having the disadvantages of either. It is one of the best designs for many reasons. This design is used mostly in industrial air compressors.

VANE

Many people are very familiar with vane pumps. If you've ever taken apart an air tool, chances are you seen one. Most electric fuel pumps have vane type pumps in them. I don't know of any manufacturer that still makes a vane type supercharger, but you might still find one around at swap meets, so they're worth a mention.



Vane type blowers have a good adiabatic efficiency, but they have some major drawbacks. The vanes in most vane type blowers contact the outer case and wear. It is difficult to lubricate the vanes without contaminating the intake charge, which can lead to detonation. There are versions of vane pumps the hold the vanes from contacting the outer housing but they cannot be turned at very high speeds due to them being out of balance, they also are very complicated in design. They also cannot pump as much air as other types of pumps of similar size, so they need to be quite large to be effective. They work ok for small engines, but you wont find one effective enough to feed even a small V-8.

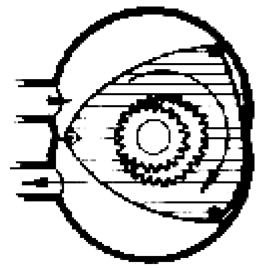
AXIAL FLOW

I cannot get too detailed about the axial flow compressor, because I have never even seen one other than pictures, but I can pass on the information that I gathered. The design is very similar to a jet engine. It was used a lot in the 50's and 60's, but it never really took off due to the production costs. It also needed to be overdriven quite a bit (500% was common) which made problems with making a reliable drive unit, 4000 engine rpm meant 20,000 blower rpm.

The unit itself was one of the most efficient designs as far adiabatic and volumetric efficiency as well as the power required to drive it. The axial flow compressor compressed air in stages, each stage having a rotor fan and a stationary stator fan. The rotor fan accelerates the air and the stator fan, which is pitched the opposite way, catches the air and changes the direction, the inertia of the air causes a pressure rise as it stacks against the stator fan. The now compressed air pushed to the next stage and gets compressed more. The number of stages varied per application but 10 or more were possible.

WANKEL ROTARY

This type of compressor is actually a form of vane compressor. The Mazda RX-7 rotary engines were based on the Wankel compressor. There is a triangular rotor with fixed vanes at each point. The rotor rather than be fixed off center, revolves around a gear that is centered in the case. As the drive gear is turned, the rotor turns as well, but also changes position (see diagram).



The rotor cannot spin freely without changing position in the case. The Wankel also make compression within the compressor, which gives it better adiabatic efficiency. It is a positive displacement compressor. I have not had any experience with adapting this type compressor for automotive supercharging, but I have worked on Mazda rotary engines. The major drawback is it is so hard keeping the rotors sealed. The rotary engine was a good design in theory, but it was hard to make them efficient. I'm sure the problems could have been solved, but I guess it was more profitable to go with a different design that was already cleaner.

OTHER TYPES OF COMPRESSORS

There are many was to compress air and any of them can be made to supercharge an engine. One type that I have never seen yet but was originally made for supercharging engines is the comprex pressure-wave supercharger. This compressor uses exhaust pulses to compress the intake air, but has a belt driven rotor that must be timed to the engine. Intake air goes in than the intake is sealed, then the exhaust side is opened and exhaust gasses enter the same cavity as the fresh intake charge compressing it. Then the intake opens and the compressed intake exits toward the engine, the intake port is then closed off before the exhaust has a chance to get in the intake. I would like to learn more about this type supercharger, but it's hard to find info. From the information I gathered, it takes very little power from the crank to run, even less than a turbocharger, and does not have any lag like a turbo. It seems that in theory, it combines the efficiency of a turbo with the low-end power and throttle response of a positive displacement supercharger. If anyone has more info on this type supercharger please pass it on (or any other type of compressor for that matter).

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SUPERCHARGER'S COMPARED TO NITROUS

Superchargers increase the density of the intake charge, which increases the amount of oxygen to allow more fuel to be burned. When you can burn more fuel, there is the potential for more power. This is the same principal behind nitrous injection. The valve events are a little different than what works well in a nitrous oxide engine, even though the result of a supercharger is very similar to injecting nitrous oxide. Nitrous oxide adds oxygen as well, but it does not pressurize the intake and this is the main effect that will require a slightly different approach in selecting a camshaft.

CYLINDER HEADS

Since most cylinder heads are not made with supercharging in mind, we will usually need to alter cam timing to mask the less than optimum intake to exhaust flow ratio. The best alternative is to increase the exhaust valve area and port flow, but this may be impractical, depending on the cylinder head.

All the cam timing variables mentioned here are going to be affected by the cylinder head. If the head is modified to work with a supercharger, the cam timing will not have to be altered as radically.

INTAKE VALVE TIMING

Since the intake charge is under positive pressure, if the intake valve is opened too early, there will be some fresh intake charge pushed out of the exhaust valve. This will hurt power and wastes fuel because you will use power to compress that charge, and then just blow it out of the tailpipe.

You will need to open the intake valve later compared to a normally aspirated engine. How much later depends on how much boost. The other end of the intake valve timing curve does not need to be too much different then a normally aspirated engine. If you're looking for all out HP and you will be doing very little driving without boost, you can delay the closing of the intake valve to better fill the cylinder, but this will cause more reversion at no boost cruising speeds in a street car. So at this point for a street supercharged engine, you need less intake duration and a later valve opening (as compared to an normally aspirated engine).

EXHAUST VALVE TIMING

As with nitrous, a supercharger makes more exhaust gasses that must be expelled. Compared to normal aspiration, a supercharger makes power in an engine differently. A normally aspirated engine will make about 80% of the power in the first 20° of the power stroke, so opening the exhaust valve early has a rather small effect on low rpm power. With a supercharger, there is much more cylinder pressure (just like nitrous). Opening the valve early will waste this extra pressure that could be making horsepower, but on the other hand, there is more exhaust to deal with. We need to open the valve early to cut pumping losses. The best solution for power here is to use a cylinder head that has a good flowing exhaust that will allow a delayed valve opening without the pumping losses.

The funny thing here is that altering the exhaust valve opening time does not show big differences in power output on a dyno. What does change is BSFC. When you delay the opening of the exhaust valve, pumping losses go up. Now this is power that is made in the cylinder and is getting used to push out the exhaust, so the power never makes it to the flywheel. On the other side, if you open the valve earlier, the power is still getting wasted, but less is used to push out exhaust. This is true for upper rpm horsepower. At low rpm it is better to delay the opening of the valve to used the cylinder pressure to make more power, there is more time to expel the exhaust at low rpm and the pumping losses are not as large. There has got to be a compromise.

VALVE OVERLAP

Due to the intake pressure being able to blow fresh intake charge right passed the exhaust valve, the amount of overlap must be kept to a minimum. To do this the cam needs a wider lobe separation angle. A typical engine fitted with an aftermarket blower operating under 10 psi of boost likes a LSA about 4-6 degrees wider than if it were normally aspirated. Usually a 112-114° LSA works well.

SUMMING IT UP

If your heads were designed for normal aspiration (which most are) and your building a street supercharged engine in the 10 psi boost range, there are a few general guidelines for cam selection. A dual pattern cam will be a must, unless you are going to seriously rework the heads for your application. Generally a dual pattern cam with 8-10 degrees more exhaust duration usually works well.

You'll need a lobe separation angle typically 4-6° wider than normal; 112-114° is common. You will also want to install the cam more retarded than a normally aspirated engine would need. Street supercharged engines generally run best with 1-2° less cam advance. Most normally aspirated engines with a matched camshaft will like about 4° of cam advance, a supercharged engine typically like only 2-3 degrees of cam advance.

Source: www.grapeaperacing.com

CAMSHAFTS FOR CENTRIFUGAL BLOWERS

Source: www.grapeaperacing.com

POSITIVE DISPLACEMENT VS. CENTRIFUGAL COMPRESSORS

Centrifugal blowers almost always have a greater adiabatic efficiency than a positive displacement blower. This results in less heating of the charge and more power per pound of boost. The problem with them is that they are high-speed devices that need high rpm to make boost, they simply cannot make boost at low rpm like a positive displacement blower.

You are also limited to how much you can overdrive them because you don't want to over speed them at the top of the rpm range. For a race car that does not need low end power, the centrifugal blower's better efficiency can make more power.

If you want low-end boost, the positive displacement blower may be a better option. Sometimes limited traction also limits the amount of power desired at low rpm. If you're already having traction problems, more power will not help the matter. A positive displacement blower could just aggravate any traction problems by increasing low-end torque.

If off the line boost is desired, a positive displacement blower has the advantage of instantaneous boost. The screw type compressor id the best of the current designs as far as adiabatic efficiency goes. They exceed most centrifugal blowers in that area. The downfall is the price tag; screw compressor rotors are not cheap to machine.

CHOOSING A CAMSHAFT

As with everything else, it's a compromise. You must decide where you want the power to be. If you want good power at low-rpm where boost is low, you will have to trade off some top-end power. The same goes for the reverse, if you're looking for maximum output up top, you will trade off low-end and throttle response. It can be a hard choice, low-rpm no boost conditions will need a completely different camshaft that higher rpm boost conditions, but you can't have everything.

At low rpm with no or low-boost levels, the best camshaft selection would be the same as a normally aspirated engine, meaning that it would have a tighter lobe separation than a camshaft used with a positive displacement blower, and installed a few degrees more advanced. For a street motor, this approach is a good compromise. As the cam starts to fall off on power, the blower will be making up for it, which will result in a flatter torque curve. This approach works well for low boost applications of about 10 psi or under. High boost levels and tight lobe separations do not work well together.

SUMMING IT UP.

If you're looking to get the most power per pound of boost and do not care about low-end drivability, then the same rules apply as with a positive displacement blower. Extending the exhaust duration, widening the lobe separation, and installing with 2-4 degrees less advance usually works well.

A wider lobe separation helps cut pumping losses by opening the exhaust valve earlier, and also helps stop fresh intake charge from being blown out the exhaust (over scavenging) during the overlap period. Adding duration to the end of the exhaust lobe helps by giving the cylinder more time to scavenge, small losses of low-end power form this can make large gains in top-end performance, so it's usually worth the sacrifice.

Source: www.grapeaperacing.com

MODIFYING HOLLEY CARBURETORS FOR DRAW THROUGH BLOWERS

Source: www.grapeaperacing.com

BEFORE YOU START

Before you go modifying your expensive carburetor(s), do something that few people do. Put them on and try them. If you selected the right carburetor(s) for your application, you should be within a few jet sizes, and modifications should be minimal.

Make absolutely sure that the engine is in good mechanical condition and that the ignition curve is dialed in. When I refer to drilling passages larger, this is a precise operation that requires precise drill bits, not a hardware store set in 16ths. Even with high quality drill bits, always mic them before you drill to verify the size. Remember, be sure that you must drill a passage, never assume. It is very easy to drill passages larger and very hard to make them smaller.

ACCELERATOR PUMPS

If an off idle stumble is present, try tuning the accelerator pump. The first step is to go up in shooter size. A supercharger acts as a large plenum, and it takes longer for the shot to reach the cylinders, so a quicker cam might also be required.

In some cases the addition of 50 cc accelerator pumps on the primary sides might be required to get sufficient pump volume. For the most part the 30 cc pumps are usually fine for street supercharged engines. I have seen larger pumps required on large cubic inch big blocks, but rarely on even the most radical of small-blocks.

IDLE FEED RESTRICTIONS

In many supercharged engines an off idle lean stumble is due to insufficient transition fuel. First check that that the throttle blades are not to far open at idle. If more than 0.040"-0.050" of the transition slot uncovered, try opening the secondary throttle plates a bit to let more air in. This will allow you to close the primaries a bit to gain transition slot area. If that does not work, some extreme cases require drilling a 1/16" hole in the main throttle plates, but this is usually only required on long duration race cams.

Once you determine that the throttle plates are in the correct position at idle and that accelerator pump tuning has little effect on the stumble, you should turn your sights toward the idle circuit. AS a test, try opening the idle screws ½ turn pas the highest vacuum reading. This may help, but not solve your problem. If it helps the stumble, it is a sign that the idle feed restrictions are too small. You can increase the size of the idle feed restrictions, but increase them only 0.001" at a time. Stock Holley's will have idle feeds in the 0.028"-0.032" range and when dealing with holes that small, 0.001" is a big jump.

POWER VALVES

When running high boost, 15+ psi, the blower can create enough vacuum under the carburetor to pull the power valve shut and lean out the engine. Some people plug the power valve and then jet up to compensate, but this is a mod that I do not recommend on street engines. Plugging the power valve will force you to jet up and kill part throttle cruising mileage. The better solution is to modify the base plate of the carburetor to give the power valve a signal form a vacuum line that is connected to manifold, not carburetor vacuum. When under boost, there is no way the power valve can close if boost pressure is against it.

The modification is simple. Simply plug the power valve vacuum supply in the throttle plate with lead shot and stake the hole so it cannot come out. Drill an adjacent hole from the font of the plate connecting it to the power valve vacuum passage. You can the press in a steel vacuum fitting and run it to manifold vacuum. This way you get a functional power valve without the risk of high speed lean out.

As far as power valve selection, the basic rule applies, at least 1.5-2 inches below cruising vacuum. Just make sure you take the vacuum reading at the point of the power valve vacuum signal.

PRIMARY MAIN JETTING

Supercharged engines need a little more fuel than a normally aspirated engine. A good starting point is about 4 jets sizes richer. You can then jet down checking the plugs and dial it in, but always start rich to be safe. Running too lean can quickly damage any high performance engine and the situation is aggravated further with boost. Rich can foul plugs and cost power, but rarely cause damage.

SECONDARY MAIN JETTING

The secondary's should go about 8 sizes richer to give a safe starting point. If you have a secondary metering plate instead of a metering block, drilling the main restrictions 0.010" larger is usually a safe bet, but it's best to go up in 0.003" increments so avoid going too rich. It's not as easy making the holes smaller as it is to drill them larger.

POWER VALVE CHANNEL RESTRICTIONS

If you find that you need more fuel, it's best not to jet up any more than 4 or 5 sizes on the primaries and 8 on the secondary's. Instead, increase the size of the power valve channel restrictions in 0.005" increments going a maximum of 0.015".

Going up too much on main jets will do nothing more than cause a rich condition in no boost conditions. Increasing the power valve fuel will only richen up the heavy load and at high throttle settings, leaving your cruising ratio untouched. If your car cruises fine and runs lean under heavy load, the power valve channel restrictions most likely need to be larger.

VACUUM SECONDARY TUNING

I usually start off with the purple spring; it seems that most of the time the purple spring is the one. If you get a bog as the secondaries come in, install the next heavier spring until its gone.

With dual carburetors, always connect the secondary vacuum cans together with a vacuum line. You can buy the covers from Holley fittings for this already installed, or you can drill them yourself, either way works fine. What this does is make sure that the secondaries open simultaneously buy insuring that they get equal vacuum.

Source: www.grapeaperacing.com

MODIFYING AFB CARBURETORS FOR DRAW THROUGH BLOWERS

Source: www.grapeaperacing.com

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ACCELERATOR PUMPS

Unlike a Holley, AFB accelerator pumps are not very tunable. You can drill the shooters in 0.002" increments, but don't go any more than 0.006". You can increase the speed and duration of the pump shot by moving the activation rod closer to the pump arms pivot point. To do this you must check that the pump piston can freely move the extra distance.

When using dual carburetors, the accelerator pumps are rarely a problem. In single 4-barrel applications, there might not be enough fuel, requiring modifications to the pump. This is generally not a problem unless it is a large cubic inch engine. Large cubic inch engines and single 4-barrel blower combinations are very rare.

IDLE FUEL JETS

If an off idle stumble is present due to a lack of transition fuel, the idle fuel jet in the idle emulsion tubes can be drilled in 0.002" increments until the sag is gone. These tubes part of the primary booster venturi cluster, and are accessible when you remove the cluster.

Once you remove the cluster, turn it upside down and the smaller tubes are the idle emulsion tubes. The idle fuel jets are in the ends of the tubes. Be careful not to drill them too large, because if you do, you will have to solder the holes shut and start over. Drilling them larger will increase idle and idle fuel flow.

METERING RODS

The AFB / Edelbrock style carburetor uses metering rods rather than power valves, but the function is the same. They increase fuel in low vacuum / high load situations. One awesome feature of these carburetors is that the springs and rods can quickly and easily be changed without disassembling the carburetor. That means no fuel spills or bowl gasket replacement like a Holley.

Start off with the stiffest springs and richest rods for a safe starting point. You can then lean it out until it bogs than got back one step richer. Metering rod and spring kits are available from Edelbrock.

MAIN JETTING

For street supercharged engines it is best to got up 0.005" on the primary main jets and use the meter rods to lean it back down if needed. In most cases even with the richest metering rods, you'll still need more fuel than the stock jets will allow.

The secondary main jets should be increased the same amount as the primaries to provide even fuel distribution.

SECONDARY AIR DOORS

In many cases there will be a bog when the secondaries open. This is due to the supercharger pulling the air doors open too fast. The solution here is to find air doors with heavier weights. Performance air doors are now available from Edelbrock, so there is no need to dig through junkyards to find big cars with carters (bigger cars like Chryslers had heavier air doors in the AFB's).

Source: www.grapeaperacing.com