SUPERCHARGING YOUR C4 CORVETTE - "A SEMI-WHITE PAPER"[1]

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OK so you are ready to supercharge your Vette. It's no longer a 'to do' or 'not to do' decision. It's now down to whose supercharging kit you should use. You are no longer afraid to take this huge leap of faith and spend $6K to $8K to $10K. Why? Because so many other Corvette owners have done it and reported good results on the Corvette Forum as well as elsewhere. Also, many new vehicles direct from the OEM are now supercharged. If the OEM's (GM, Ford, Acura, etc., etc., and Chrysler) approve of supercharging it must be ok to do the same to my vehicle – right ? So how do you choose from amongst the various supercharging systems that are available? What differentiates one kit from another? What differentiates one compressor style from another, i.e. centrifugal, Roots, rotary screw, etc. What differentiates one manufacturer from another, i.e., Vortech versus ProCharger versus PowerDyne? Should the charger oiling system be self-contained or fed by engine oil? Do I intercool and if so what's the difference between a mechanical air to air intercooler, a mechanical air to water intercooler, and/or "Gaseous Intercooling[tm]" . Decisions, decisions, decisions[12] …

In choosing a supercharging system for your Corvette you must first define your needs and usage. In supercharging any vehicle there are advantages and disadvantages to each type of system. A well-engineered system minimizes the trade offs between them and optimizes the choice for the particular application. The decision you have to make is an important one. You are going to live with your decision everytime you get into your Corvette and drive it. It is unlikely, if you make the wrong decision, that you will have sufficient funds to go back and re-do it. Nor will you psychologically want to admit to yourself (let alone anyone else) that you screwed up and chose poorly.

I am going to help you make that decision. Yes I want you to buy your hardware from me. In return for so doing you will benefit from my help, knowledge and ability to help you successfully supercharge your vehicle.

The following are the key areas that must be addressed when supercharging your C4 Corvette.

- COMPRESSOR
- SUPERCHARGER LUBRICATION
- INTERCOOLERS
- FUEL DELIVERY, i.e. injector sizing.
- FUEL PUMP(s)
- IGNITION
- PISTONS
- ENGINE COOLANT
- HARMONIC BALANCER
- CRANK PULLEY SIZE
- ECM / PCM PROGRAMMING
- MAF Sensor
- APPEARANCE, FUNCTION & FORM
- UPGRADEABLE/EASE OF INSTALLATION
- "FINISHED PRODUCT" / EXPERIENCE

COMPRESSOR

To the best of my knowledge there is currently available in complete kit form only centrifugal based supercharger systems. That's not to say you could not create your own say Roots/Eaton or rotary screw style system, but my purpose here is to limit the discussion to what is readily available.

There are currently three centrifugal style crank belt driven compressors (supercharger) to choose from that are part of complete bolt-on supercharging kits for your Corvette. The three major manufacturers of centrifugal compressors are Vortech/Paxton, ATI (ProCharger), and PowerDyne. Each company produces an excellent compressor.

A centrifugal compressor is a sophisticated fan. It is very efficient as compared to a Roots style compressor and has virtually no upper limits. However to maintain efficiency the compressor should be properly sized to the application. A turbocharger is a centrifugal compressor. The centrifugal supercharger is belt driven off the crank pulley. The turbocharger is exhaust gas driven by a turbine shaft coupled to the centrifugal fan. Turbochargers are very efficient because they utilize otherwise normally wasted exhaust gas heat. We will not compare turbochargers to centrifugal superchargers in this discussion. As always there are advantages and disadvantages to each.

One disadvantage (or to many motorheads advantage) to the centrifugal supercharger is gear noise. Several years ago Vortech Superchargers introduced their SQ trim blower which is very quiet, but not noiseless. Since that time ProCharger has also introduce a quiet blower using helical cut gears. Centrifugal superchargers are fans and as such build boost with RPM. Centrifugal compressors are not "positive displacement" pumps as are the Roots style (Eaton) & rotary screw compressor style (Whipple & KenneBell). Centrifugals are very forgiving if your engine should hiccup and backfire. Unlike a positive displacement blower they do not require a safety POP OFF valve. Centrifugals build boost as the square of RPM. This means the boost pressure rises rapidly as a function of engine RPM – a real advantage. Another advantage of centrifugals is the amount of power they draw from the engine as a function of engine RPM and the work done. No work done no power drawn, i.e., even at high RPM if the throttle is closed the compressor draws virtually no power (less than a fraction of 1 HP). And because the power drawn by the compressor increases as the cube of engine RPM a centrifugal draws virtually no power at low RPMs while cruising and is incredibly efficient for a daily driver.

Centrifugal Fan Laws: $CFM1/CFM2 = RPM1/RPM2 = [SP1/SP2]^{\frac{1}{2}} = [BHP1/BHP2]^{1/3}$

It is my opinion that the centrifugal supercharger is an overall best choice for a high HP to weight ratio vehicle like the Corvette. Alternately if we were discussing supercharging your heavy SUV that you use to tow your boat with my first choice would be a positive displacement rotary screw.

SUPERCHARGER LUBRICATION

The Vortech, Paxton and the ATI compressors contain gears and require lubrication. The PowerDyne compressor is “oilless” because it uses a small cogged belt and ceramic bearings. The Vortech, Paxton Novi and ATI compressors utilize step-up gears in the neighborhood of 3.4 to 4.4 to 5.1. The step up ratio gears are required because the “fan blade” inside the blower must spin up to 60,000 or more RPM in order to produce the required boost levels. The optimum fan blade RPM is determined by blade size, desired boost level, and engine displacement. At these RPM’s the lubrication requirement is quite important. Until recently these blowers all used engine oil and pressure to deliver a spray onto the gears thru a small (typically .030 to .040”) nozzle. The oil then drains back by gravity to the engine oil pan – much the same as in a turbocharger. There are two drawbacks to using engine oil for lubrication. First the initial installation time is much greater: typically requiring removal of the engine oil pan. Second, should the compressor bearings fail and you continue to drive you may drop bearing debris into the engine oil pan. It’s not the end of the world but you will have to drop the oil pan and clean.

Vortech, Paxton, and ATI have all introduced a line of compressors utilizing a self-contained oiling system. This enhancement greatly reduces the installation time of the supercharger system and hence the price you pay the installer. The biggest disadvantage to this system is the required oil change every three to 6,000 miles – not bad. And of course with the self-contained lubrication system if the blower crashes there is no risk of engine damage from “debris” in the oil pan.

Note that the bigger the step-up ratio of the given supercharger the bigger a drive pulley you can run to obtain a given boost level. The bigger the pulley the better: bigger pulley equals more belt surface area and less belt slippage. Bigger pulleys are a big advantage if you are fighting belt slip which we will discuss later.

One disadvantage to a compressor with a self-contained oiling system is its’ inability to remove “unwanted heat” under sustained high power operation. For a street driven vehicle this is probably not a factor.

My choice when practical is to go with the engine oil lubricated blower. First, engine oil removes heat from the supercharger – the oil is a coolant removing heat the same way it removes heat from the engine. Please note that an efficient centrifugal compressor may typically require at least 20 HP to make 5 pounds of boost into a 350 cubic inch engine. At 15 pounds of boost pressure into a 350 cubic inch engine the same compressor may require 50 to 100 HP to drive it! Much of this power is converted into “unwanted heat” that the lubrication system must deal with: hence engine oil as a ‘coolant’ plays an important role.

Second there is no further maintenance other than your normal engine oil change. All Carroll kits utilize an Earl’s in-line supercharger oil filter. Although expensive and more time consuming to install, this filter guarantees the blower an ultra clean supply of engine oil.

AIR INLET

As a side note here let me put in my 2 cents worth on the location of the supercharger air filter. At first glance you'd think what idiot located the air filter directly above the exhaust manifold! After extensive testing (temperature probe inside air filter) we found that the inlet air temperature to the supercharger only a few degrees F above ambient as long as the vehicle was moving! This is due to the way outside air flows thru the L98/LTx engine compartment. The negative pressure under the vehicle draws fresh air down over the filter. In fact we found a power DROP by remoting the air filter to the battery box (of course after moving the battery). This is due to the fact that centrifugal compressors are very sensitive to ANY inlet restriction. Centrifugal compressors love to 'push' hate to 'pull'. Except at idle with a standing vehicle we found no advantage to remoting the filter and in fact a power loss. Those creative individuals who have designed air scoops and moved the filter up a pinch with a short BIG tube are on the money. However, once the vehicle is moving the air temperature difference is insignificant.

INTERCOOLERS

To intercool or not to intercool that is the question. Actually it is not a question when supercharging the C4 Corvette – you must intercool in order to maximize your net power! The real question is which type of intercooler is best for your application. Here-in lies a significant difference between the approach I have taken versus most others. Let's look at the differences.

Whether you call it an intercooler or aftercooler and no matter if it is an air to air or water to air intercooler, it is still a mechanical radiator designed to dissipate the heat of compressing air by flowing ambient air over some form of extra radiator (not to be confused with the vehicle's engine coolant radiator). No matter what style compressor you choose it will heat the air as it compresses it – fact of life and the second law of thermodynamics. Ever touch a shop air compressor while it is running – warm to hot - right? So why would anyone design an automotive supercharger kit without one? Good question, but the answer may not be so obvious.

The first parameter we must examine is the boost level and compressor efficiency. When dealing with a centrifugal blower (compressor) making 5 to 7 pounds of boost the answer may not be so obvious. At 5 pounds of boost pressure a well designed centrifugal will raise the ambient air temperature about 50 degrees F. In order to cool the compressed air the given heat exchanger using the same ambient air would have to be huge. Think about what I am saying. Let's say the ambient air is 85 degrees F, a typical summer day. If the compressor adds 50 to this we are at a supercharger discharge temperature of 135 degrees F. In order to cool the 135-degree air with 85 degree we'd require a big intercooler because the difference between the heated air and the outside air is not that great. Besides, thermodynamics tells you the 135-degree air can only approach 85, never get there ! Additionally, if you put a big intercooler on you will have a pressure drop thru it and consequently have to spin the compressor faster to compensate for the pressure drop and therefore you heat the air some more.

Remember that the increased power the blower draws comes right off the crank pulley and increases as the cube of the RPM^2. The law of diminishing returns kicks in and tells us that until you get up to at least 10 pounds of boost pressure an intercooler may actually penalize performance rather than increase it !!! There must be an alternative – no?

Yes there is and it is called Gaseous Intercooling[tm] , i.e., water/alcohol injection. Carroll Supercharging pioneered water/alcohol injection for the L98 Corvette in 1987. (In fact I started using water/alcohol injection in 1970 on my supercharged Dodge Van with a '340' running 10.5:1 pistons.) We coined the term Gaseous Intercooling[tm]. In 1987 the only available centrifugal supercharger was the planetary "ball drive" Paxton producing 5 to 7 psig. It was impractical to couple the Paxton to a mechanical intercooler at this boost pressure (the charge air was not that hot and the Paxton was incapable of dealing with the pressure drop thru an intercooler), however we still needed to suppress detonation[3] in order to produce maximum power. Recurving the spark curve and taking out 15 degrees of timing was not acceptable – too much power loss (typically each degree of timing equates to a 1% power loss or gain). Hence we applied water/alcohol injection – the same solution the Allies used on the centrifugal supercharged fighter planes during WWII. At present Carroll is the only manufacturer that incorporates Gaseous Intercooling[tm] as standard on all its Vette supercharging kits.

Many ATI and Vortech owners have purchased and installed the Carroll Gaseous Intercooling[tm] system on their mechanically intercooled Corvettes and found more power. The two types of intercooling are not mutually exclusive – rather they often compliment each other. More on Gaseous Intercooling[tm] later.

Least we forget there are several additional things you should know about mechanical style intercoolers. First and most important remember that the intercooler cannot reject any heat unless there is air movement thru it, i.e., where does the heat go, if it goes anywhere, when stopped at a traffic light? Second, if the "radiator" (intercooler) is placed in front of the engine radiator then the heat of rejection of the intercooler may affect the operation of the A/C on a hot summer day while in stop and go traffic. Also, depending on the size and placement of the intercooler, the heat rejection of the compressor may affect the engine radiator. Last consider their complexity when doing routine servicing of your Corvette. To the die-hard racing enthusiast the above is inconsequential. For the Corvette owner who does not do his own work and simply wants a fast and reliable daily driver the above should be taken into consideration.

Finally a mechanical intercooler is a hindrance when not in use, i.e., most of the time ! First and foremost is fuel efficiency. If you want to keep the awesome mileage your Vette gets on the highway under cruise control you do not want cooled air. Warm or hot air is better for fuel vaporization. If you have an air to air intercooler you are going to have to rig up some kind of by-pass valve while cruising (the normal surge valve does not bypass the intercooler). If you are running a Carroll kit with Gaseous Intercooling[tm] rest easy – it only operates while under boosted conditions, i.e., when the pedal is to the metal !

Is there an application where a mechanical intercooler should be used? Absolutely the answer is yes. If you plan to run boost levels in excess of 12 psig then by all means you should have one or the other of the two types of mechanical intercoolers and possibly our Gaseous Intercooling[tm] as well.

FUEL DELIVERY

We have already addressed a major difference between 'us' & 'them', i.e., Gaseous Intercooling[tm] for 'us' versus mechanical intercooling for 'them'. Gaseous Intercooling[tm] or water/alcohol injection contributes to the ideal air fuel ratio[4] under boost. Our supercharging kit utilizes a 15 GPH (gallons per hour) water/alcohol injection nozzle. A 50/50 blend of distilled water and alcohol weighs about 6 pounds per gallon at 60 degrees F. That's 90 lb/hr (15 x 6 = 90). A rule of thumb for calculating fuel injector size at WOT (wide-open throttle) is each horsepower requires .5 (1/2) pound of fuel per hour[5]. Premium gasoline weighs 5.994 lbs./gal. Hence each gallon of gasoline can support 12 HP (5.994/. 5 = 12). Therefore our 15 gallon/hour water/alcohol nozzle can support an additional 180 HP (15 x 6 / .5 = 180) out of the total fuel requirement[5]. This is the reason we were able to utilize the stock fuel injectors on our Stage I kit and obtain such great fuel efficiency even under boost. Today, we replace the stock injectors with new larger ones due if nothing else to age.

When supercharging a 1985 thru 1993 there is another fact you must be cognizant of: simultaneous or "batch" fired injection versus sequential injection. **ALL** 1985 thru 1993 Corvettes utilize simultaneous or "batch" fired injection, i.e., all 8 fuel injectors fire simultaneously every revolution (360 degrees[7]) of the engine. Newer engines (1994 & later) utilize sequential injection. At idle this means the typical injector on a sequential engine fires once every 720 degrees of crank rotation for about 2.0 milliseconds. Because the simultaneous injection or "batch fired" engine fires the injector twice for each power stroke, injector sizing is a little more critical and limited. Putting 60 lb/hr injectors into an L98 is the equivalent of a 120 lb/hr injectors in a sequential engine. The E-Prom must be calibrated for the bigger injector or it will create havoc at idle. The largest injector I recommend for the 1985 thru 1993 ECM is a 60 lb/hr for excellent driveability etc. Once above 1500 RPM or so injector sizing is not as critical. If you want to exceed 800 RWHP on a 1985 thru 1993 Corvette you might want to consider the use of an aftermarket PCM such as the FAST XFI in a sequential mode.

If your engine is "batch fired" your choice of whose supercharging system you go with should be somewhat dictated by how the required extra fuel is delivered. Recall that a Carroll kit with Gaseous Intercooling[tm] requires less extra fuel per extra horsepower. Consequently you can make more power with a Carroll kit utilizing smaller injectors than our competitors. Ultimately more power means more fuel: sometimes a change of injectors and always a higher capacity fuel pump(s). It's easier tuning wise to use the smallest size injector that gets the job done – you'll get better bottom end and mid range power with a smaller injector not to mention better gas mileage while cruising. Size the injector for peak power on a "batch" fired engine and no more. Our Stage I supercharging kit will deliver more average power under the power curve pound for pound of boost than any competitor.

FMU's

FMU's are required when you cannot or do not want to change the engine's fuel injectors. I have used them quite successfully in the past. Given the proper fuel pump set-up I do not have any particular issues with them. However, my kits no longer require them as I have overcome all of the previous issues with locked up software and injector pulse width caps built into the GM software. But if for some reason you are still using a FMU there are a few facts you should be aware of.

FMU's are nothing more than a fuel pressure regulator very similar to what's on your Vette now. The big difference is the ratio or multiplier. The stock fuel pressure regulator raises the fuel pressure 1 psig for each increase in manifold pressure of 1 psig. Aftermarket FMU's increase fuel pressure with boost at a specified ratio, typically somewhere between 4:1 all the way up to 12:1 resulting in rail pressures from 70 to 100 psig !!! 1985 thru 1987 Corvettes utilize a Bosch or Rochester pintle style injector that can work with these elevated pressures. Beginning in 1988 and right thru 1993 Corvettes utilize the Delco Multech disc style injector and will not work reliably at elevated pressures. Much beyond 60 psig the injector may not open at all !!! The 1994 thru 1996 MulTech injectors can handle higher pressures. So if you have added a FMU to a 1988 thru 1993 Corvette you ***MUST*** change the injectors. The Ford Blue top 24 lb/hr saturated style injector is a good place to start. If you choose the Ford Red top 30 lb/hr injector you must use a recalibrated E-Prom on 1985 thru 1993 Corvettes. On 1994 – 1996 PCM's a re-flash is required.

This brings us full circle to the in-tank fuel pump. Most kits include an extra in-line fuel pump. Without the booster pump the FMU will never see enough pressure to work. Even with the booster pump the in-tank Delco stock pump is marginal at best.

All of our C4 supercharging kits include a new powerful very quiet Walbro in-tank fuel pump that replaces the existing Delco. Installation on the C4 is simple and takes only minutes. External supplemental fuel pumps can produce an annoying "whine" that you must live with ALL the time while driving! We avoid the booster pump if we can, however eventually more power means more fuel. The Walbro in-line GSL-392 is very quiet and can be barely heard.

As you climb up the power ladder you will need larger injectors. These are included on Stages II thru IV.

FUEL PUMP(s)

A question that is often asked of me is, "don't I need to increase the size of the fuel line"? The answer is most often, "NO"! A 3/8"id fuel line (standard on all C4's) can easily support 1000 HP! The key to sufficient fuel supply is pumping power. As an example let's look at a flow of 1 gallon per minute at a required at the fuel rail pressure of 60 psig. That is enough fuel to support 720 HP. The pressure drop thru a 3/8"id line at 60 GPH is less than 1 psig[8]! Switching to a ½" id line would result in a pressure of about 1/10 of the 3/8" line. However, given sufficient pumping power, a 1 pound drop versus a .1 pound drop is insignificant. At 500 HP the pressure drop is even less.

Much more important is fuel pump selection. A C4 fuel pump can flow about 35 GPH at 55 psig. That's enough fuel to support about 420 HP. Note though that 55 psig is barely adequate

at 5-7 psig of boost pressure. As boost pressure rises so must fuel pressure. If you are using a FMU a booster pump is mandatory.

All Carroll C4 kits include a new High Output Walbro GSS-340 in-tank fuel pump that can flow 255 L/Hr @ 43.5 psig. That's enough fuel to support over 700 HP @ 60 psig. When required we supply an additional Walbro GSL-392 in-line fuel pump that mounts behind the license plate that can support 850 HP @ 60 psig !!! Add a voltage booster like the Kenne Bell BAP and these two pumps in series can support over 1000 HP.

Alternately you can mount a Bosch 044 behind the license plate (my opinion easier than using it as an in-tank), remove the in-tank pump and just leave the sock and support 850 HP all by itself.

IGNITION

Of extreme importance is spark plug selection. Stock heat range spark plugs can significantly contribute to detonation. Detonation (called 'ping' if slight or 'knock' if heavy) even for a second or two can 'crack' a cast piston at the higher engine RPM ranges and must be avoided at all costs! All Carroll kits include spark plugs that are two heat ranges colder than stock. You should always run the coldest plug that does not foul under normal driving conditions. We have NGK plugs that are 3 or 4 heat ranges colder than stock for extreme conditions, i.e. over 650 crank horsepower.

The Corvette L98/LT1/LT4 eight cylinder engines with a distributor ABSOLUTELY require some sort of CDI (capacitor discharge ignition, e.g., MSD 6A) at boost pressures of 10 psig and engine RPM's above 5500. The GM HEI and Opti-Spark systems simply cannot fire a supercharged engine[9]. The reason is simple. At a battery voltage of 13.6V past 5200 RPM there is insufficient time to saturate the ignition coil. Remember thru the distributor on an 8 cylinder engine the spark coil must charge and discharge every 90 degrees of crank rotation (720/8=90). At 6000 RPM this equates to 2.5 ms! A CDI ignition system overcomes the problem by raising the coil voltage from 13.6 to typically 400V. Power (watts) is equal to the voltage times the current. Hence you can see why a CDI system dramatically increases the available spark current in a much shorter time span.

All Carroll kits (excepting Stage I - L98) include a MSD – 6M (fully encapsulated marine unit) and a Helicoil[10] wire set. Stock GM carbon core wires are not acceptable when using a CDI system.

PISTONS

All stock 1986 thru 1996 L98/LT1/LT4 Corvettes come equipped with "hyperutectic" pistons. Hyperutectic is a fancy way of saying cast. These cast pistons are extremely strong and light: maybe half the weight of a forged piston. Light pistons reduce the rotating mass which results in more useable power. The disadvantage to cast pistons is that they are fragile and subject to cracking. Forged pistons are denser (a result of forging as opposed to casting) and consequently less subject to cracking.

Engine detonation (ping or knock) results in a shock wave being sent down the cylinder while the piston is coming up the cylinder. The resulting noise you hear is the piston rattling in the

cylinder. Detonation is extremely damaging. The piston rings collapse as the shock wave passes and the piston bangs against the cylinder wall creating the noise you hear. Not only is detonation damaging to the piston but it also results in pressurizing the crankcase and ultimately rod bearing and crank bearing damage.

Detonation at the higher engine RPM's can result in a cracked cast piston in less than a second. Once the piston cracks you are done. The engine will continue to run but there will be excessive blow-by even at idle. At higher power levels under boost you will typically push the oil dipstick right out of its' dipstick tube. Tying down the dipstick will not fix the problem. It is easy to tell if you have cracked a piston(s). At idle simply remove the engine oil fill cap. Any "puffing" (even w/o smoke) is a telltale sign of a cracked piston. More than one cracked piston will usually result in a rough idle as well.

Utilizing forged pistons may stop cracking them but it will not stop bearing damage and ultimately engine failure.

Although the "hyperutectic" piston can handle the horsepower we recommend forged pistons above 425 crank HP because the detonation can come on so quickly and damage the cast piston.

ENGINE COOLANT

There are two things you should not do with a supercharged engine: use too much glycol and/or slow down the water pump.

- NEVER use more than 40% glycol. Pound for pound water at its' higher specific gravity can carry away more heat (BTU's/LB) than a water-glycol mixture. At 50/50 water-glycol you have reduced the engines' cooling capacity 10%. A supercharged engine produces more power and hence more heat. In order to reject this heat a 60/40 mixture of water-glycol is more efficient. In fact, if you are having detonation or overheating problems try using 10% glycol (for corrosion protection). Naturally if the car is to see winter freezing weather you must use more. Also always use distilled water – never tap water full of minerals.

- NEVER slow down the water pump with an under drive pulley set. This is a sure formula for increasing detonation. Without going into great detail you want what is called "turbulent" flow thru the heads and radiator. Turbulent flow picks up and rejects more heat than laminar flow. Turbulent flow results from high coolant flow velocity. It is critical to suppressing detonation that there be turbulent flow thru the heads. It is the turbulent flow around the combustion chamber coolant surface that quickly recondenses the tiny boiling bubbles resulting from the high combustion chamber temperatures. Do not believe the old "wife's tale" about the water going thru the engine or radiator too quickly and unable to transfer heat. This is a complete falsehood!

The engine's water pump is another type of "centrifugal pump". Like the supercharger you do not want the water pump to cavitate. This is unlikely even at high engine RPM's unless there is a restriction on the **suction** side of the water pump. So make sure the hose to the water pump is 'big' and 'stiff'.

HARMONIC BALANCER

All L98's utilize a keyed crank and balancer and as such there are no "spun balancer" issues. Beginning with the LT1 (1992) GM in its' infinite wisdom decided to eliminate the keyway on the hub for the balancer/crank pulley. The keyway on the crank is **still** there! It is my belief GM did this to annoy us supercharging freaks and make our lives most difficult – just kidding! What this means to you is that the pressed on hub is at risk of coming loose when you add the additional load of a blower. Remember the blower can easily draw 50 HP – 100 HP off the crank! All Carroll LT1/LT4 supercharger systems include an ATI keyed SuperDamper^{tm}. There is a distinct advantage to using this damper besides it being keyed – it enhances HP and engine life. This damper is compatible with all Vortech and ProCharger supercharger kits. Note here ATI refers to ATI Performance Products Inc. out of MD and not ATI of Accessible Technologies Inc. the ProCharger people.

ECM or PCM PROGRAMMING

Regardless of whose supercharging system you purchase the ECM (Engine Management Computer) must be re-programmed. On newer Vettes beginning in 1994 the ECM became the PCM (Power Train Computer) because it controls more functions than just the lock-up torque converter on the automatic transmission. On the 1985 thru 1991 L98 and 1992/93 LT1 Corvettes every one of our kits includes a new custom e-prom. You simply pop out the existing Mem-Cal pack, plug it into the supplied adaptor board that includes our e-prom on it and insert the assembly back into your ECM. In fact, if you want we will supply you with the Moates Ostrich that allows real time tuning !!!!!!!! And we will help you to learn how to tune your ride!!!

On 1994 thru 1996 LTx Corvettes we re-flash your PCM with our own custom program tailored to your ride. Or you can buy the software to do your own programming and we will supply you with a starter program.

APPEARANCE FUNCTION & FORM

Our design philosophy is a little different than our competitors. We believe that most Corvette owners are very picky and do not wish to trade off beauty or amenities for more power. Hence many of our engineering decisions were based upon this philosophy. We think our professional C4 supercharging system has accomplished this goal. Our hardware is beautiful to look at as well as beautifully finished. Our hardware is quiet and *very* functional. Our supercharging system is easy to service.

UPGRADEABLE

Obviously anybody's kit can be upgraded with enough time and effort. However we are proud of the fact that we publish our formulas for more power. You are welcome to use them regardless of whose system you purchase.

EASE OF INSTALLATION

Manufacturers tend to drastically minimize their installation times in order to make the sale: we don't !!! Most stated installation hours are unreal for two reasons. First the hours are based upon repetitive installs where the installer has it down to a science after doing many installs. The installer has learned all of the appropriate shortcuts and may have special tools. Second the installer is being paid and must hustle in order to stay competitive and make money. Being profitable is an essential ingredient of staying in business. Being profitable is not necessarily

equated to a quality installation. A clean professional install takes time. There is nothing difficult about installing one of our kits but it does take a lot of time (typically 40 hours) to do a quality and beautiful looking installation. You can purchase one of our Installation Guides for your C4 (costs may be applied to future kit purchase). It contains well over a 100 pages. It is full of detailed photos and descriptions. It contains wiring diagrams and some OEM pages.

Some people may be overwhelmed by its' size, however it guarantees you a factory like install. Additionally we feel it is important to be honest about the install hours, particularly if you are paying for the install. If the installer quotes less hours than we state he may take short cuts when under the gun to be profitable.

WARRANTY

All of our parts are unconditionally guaranteed for one year less shipping. Our warranty does not include nor cover inconsequential damage to your vehicle. If you destroy your engine you are responsible !!! Stage I kits may have the supercharger warranty extended to 3 years thru Vortech Engineering.

"FINISHED PRODUCT"

A "Finished Product" is a piece of hardware that has gone thru many generations of development. Remember the old adage of not buying a new car when first introduced? No matter how good the engineering there will always be bugs. It is impossible to turn out a perfect product the first time, or even the second time, or even the N^{th} time? When you buy a new car at the end of its' life cycle (for instance the 1996 LT1) you are buying what GM would call a "Finished Product". Not perhaps the most technically advanced but refined and reliable. All of the bugs have been worked out.

So, does experience count? If it does Carroll has it!!! We have been building and selling these kits with the Vortech blower since 1990: longer than any other manufacturer. We first started building these kits with the Paxton ball drive blower in 1987. That is almost 17 years ! Do you think we've gotten it right?

DOES THE SHOE FIT THE FOOT ?

Your first question must be do I want a reliable daily street driver or an all out killer track vehicle. Your next choice is how much power (and be honest here) do you want to make. Next perhaps does fuel economy matter to you? Do you want the exterior of your Corvette to appear stock? Finally, is noise a deciding factor, i.e., do you want to be noticed or is it more important to you that your Corvette sound exactly like the original factory unit?

In my opinion if all you need or want is an extra 100 HP and want to maintain excellent fuel economy then by all means go with the Carroll Stage I utilizing a Vortech SQ quiet trim supercharger – you won't experience buyer's remorse! Also, it is upgradeable to any power level you may desire in the future. Other than occasionally filling the water bladder for the Gaseous Intercooling^{tm} there are no trade offs in reliability, derivability, noise or fuel economy!

After reviewing the above you decide which 'shoe' fits your 'foot'.

CONCLUSION

It is my belief that the Carroll system with its' Gaseous Intercooling[tm] technology is by far your best choice for a reliable daily driver. It is a beautiful piece of artwork. There is no bulky intercooler, no dangerous pinging off the line, and no compromising of your A/C on a hot summer day in stop and go traffic. It is extremely easy to service, offers awesome fuel economy, and is very stealth, i.e. no blower whine!

However, if you must have a supercharger with a self-contained lubrication system and an air to air intercooler than by all means purchase the ATI !!! Let me quote you a price – we do not have the "not invented here disease"; we simply want your money LOL !!!

FOOTNOTES:

1. A White Paper is supported throughout with technical engineering documentation used to prove the presented ideas and/or facts. My intent with this paper is to simplify the presentation for the average reader as well as promote my product(s) and hence I coin the term "Semi-White Paper".
2. Centrifugal Fan Laws: American Society Of Mechanical Engineers
3. The detonation was the result of the increased charge density and the then current combustion chamber design: not charge air heat.
4. Ideal A/F ratio under boost for max power should be between 12.5:1 and 13.0:1. Many tuners prefer 12.0 to 12.5:1 for safety reasons.
5. Carburetored engines require ½ pound of fuel per hour @ WOT. I also use .5 lb/hr for fuel injection to create a safety margin. .4 or .45 lb/hr is often used for fuel injected engines.
6. *The High-Speed Internal Combustion Engine* by H. Ricardo
7. A 4-stroke engine rotates 720 degrees for each power stroke. The intake valve at idle is only open for a few degrees out of the 720. Hence the fuel puddles at the intake valve on a simultaneously fired engine until the valve opens.
8. *Cameron Hydraulic Data* by Ingersoll-Rand
9. Excepting our Stage I L98 where the engine RPM does not exceed 5200.
10. Helicoil ignition wires incorporate a thin stainless steel wire spirally wound around the outside of the carbon core. The carbon core must be retained to suppress ignition noise. All major manufacturers of aftermarket performance wire sets utilize this technique.
11. 6000 revs/min x 1min/60sec x1sec/1000ms = 6revs/60ms or 60ms/6revs or 10ms/rev @ 6000 engine RPM
    HENCE @ 6000 RPM = 20ms MAX time to inject fuel
    5000 RPM = 24ms MAX time to inject fuel
    4000 RPM = 30ms MAX time to inject fuel
    3000 RPM = 40ms MAX time to inject fuel
    NOTE: 1985 THRU 1993 SCANNERS READ INJECTOR PULSEWIDTH PER REVOLUTION, i.e. ½ of above table. Example at 6000 RPM if your scanner reads 10ms PW you are at 100%. Beginning 1994 scanners read PW per 720 degrees. Example @ 6000 RPM if your scanner reads 20ms PW you are at 100%. Any PW number greater than that shown at the given RPM above is meaningless.
12. This paper will not address turbo charging a C4 as it is my belief this method of increasing power need be left to the "Professional" ! You can always produce maximum power with a turbo charger since it uses waste energy, i.e., exhaust gas heat. However, turbo charging, unless done by the OEM or a Professional, brings with it many problems that are not only beyond the scope of this paper but most Corvette owners.