944 Turbo Engine Performance Modifications

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Introduction

Ask ten different people about modifying a 944 Turbo (951) engine, and you'll typically get about twenty differing opinions. The bottom line is there is no single best way to modify a 951. Otherwise, there wouldn't be so many different aftermarket performance parts suppliers out there. Each car is a special case and modifications should be tailored to each individual's needs, desires, and pocket book.

The best advise I can give you is to decide very early on what you want to do with the car. In other words, ask yourself exactly how much performance you want out of the car. But remember, as you approach the physical limits of the car's capabilities, performance modifications will become exponentially more expensive. As a Porsche mechanic friend of mine told me early on, "Speed Costs, How Fast Do You Want To Go?"

Next, I'll tell you that although it costs a lot of money to achieve an ultra-high performance 951, you don't have to be rich to get there (although it does help). However, it will take you longer to get there and it requires a great deal of careful planning, timely purchases, and most of all, a great deal of patience on your part. Heck, I started modifying my 944 Turbo as soon as I bought it in 1993 and have been modifying it constantly since then. When will it end for me? Well, as long as there is new stuff available to try, the aftermarket parts vendors will probably continue to have their claws deep in my wallet. But, for me it's an addiction. I remember a quote from Robin Williams some years ago which went, "Cocaine is God's way of telling you that you're making too much money." 944 Turbos are MY cocaine.

With regards to saving money doing performance modifications, the best way to save money is to learn to do some or all of your own work. This in itself can become costly when you start buying tools - especially some of the specialty tools. However, if you plan to keep the car, the investment in a good set of tools will pay for itself over the long haul. Hopefully, the Shop Manual portion of this web site will help you learn to do some of your own maintenance, modifications, and repairs. I had done work on some of mine own cars up until I bought my 951 in January of 1993. I started doing some of mine own maintenance then but, never really started doing all my own maintenance until early 1996 when I moved to south Jersey. I struck up a friendship with a mechanic there (Chuck Oliver), and under his tutelage, learned to work on Porsches, Ferraris, Mercedes Benz, and others. To this day, Chuck is one of the few people other than myself that I would trust to work on my car. I'd also help him hide a body if he asked.

In this particular discussion, we will deal only with engine performance modifications. Suspension and brake modifications will be discussed in other procedures. For the most part, I will stay away from making recommendations about specific products. What I will do at the end of this procedure is provide a list of various performance parts suppliers and some of the things they offer. Then, it will be up to you to decide what is the best course of action for your particular needs. Now that I've bored you to tears with all of the preliminary stuff, let's get down to business.

Computer Chips

You absolutely can not buy horsepower for a 944 Turbo cheaper than investing in a set of computer chips. For a little more than \$500 USD, you can install a set of chips in your DME and KLR and pickup as much as 60 HP. They really make a huge difference in the performance of a stock 944 Turbo.

So, how do the chips achieve these horsepower gains? Well, most of them function in essentially the same fashion. 944 Turbos run a maximum stock boost of around 11 psi with an overboost protection set somewhere above that (don't remember exactly where). Aftermarket chips will raise or in some cases eliminate the overboost protection set point and will raise the maximum boost pressure allowed by the boost control system (typically to around 14-15 psi). In addition to the setpoint increase for the boost control system, some setups may come with a device to retard the pressure build up from the turbocharger discharge to the wastegate. Typically, you'll see this in the form of an orifice in the sensing line from the turbocharger discharge to the cycling valve (which controls the wastegate) or by use of a bleeder valve in the line from the cycling valve to the wastegate. For a complete description of how the 951 boost control system works, refer to the 951 FAQ. Also, within the chip set, the fuel and ignition maps are typically modified to match the engines demands at the new higher boost levels.

The advantage of using chips is, as we said before, that they are relatively inexpensive for the amount of horsepower gained. They are also relatively easy to install and are well within the capabilities of most shade tree mechanics with a limited number of tools. So, what are the disadvantages?

First, for the chips to work to maximum advantage they have to be matched to the system you're running. If you're starting out with a completely stock 944 Turbo, that's not a problem. However, if you install a set of chips and then down the road decide to make other modifications (i.e. different turbocharger), your chips are no longer matched to your system. So, now you have to try and get another set of chips which are matched to your new setup or you have to pay someone to custom map you a set of chips. That can become costly in a big hurry.

In theory, you could have a set of chips custom mapped for any setup you decide to use. However, the costs in dyno time along would quickly make such a practice prohibitive. If don't plan to do a lot of performance modifications, a set of chips is definitely the way to go. However, if you think you're going to want other modifications down the road, chips are a waste of money because you'll eventually end up throwing them away. In that case, you're better of saving up your money for a fuel management or stand alone engine management system.

Air Flow Measurement

Accurate air flow measurement is the single most important variable in any engine management system. The stock air flow meter is a "barn door" type air flow measurement where a door or gate inside the units swings open to various positions based on the amount of air flow through the sensor. These also use a temperature sensor for density compensation of the air flow signal.

Mass Air Flow (MAF) sensors use a heated wire element. As air flow increases across the wire it cools changing the resistance of the wire. The measured resistance of the wire can be directly correlated to a specific amount of air flow across the wire. MAF systems may or may not use an inlet air temperature sensor for density compensation.

Manifold Absolute Pressure (MAP) sensors measure the pressure in the intake manifold. It is then density compensated by a signal from an inlet air temperature sensor to determine the amount of air flow into the intake manifold. The use of MAP sensors is a fairly recent addition to the 944 performance market and are primarily being used with stand alone engine management systems. The great advantage for both MAF and MAP sensors is that they typically provide a more accurate measurement of air flow than a barn door meter and they also eliminate a huge restriction in the air flow path coming into the intake manifold.

MAF and MAP systems may be controlled via a special set of chips for the stock engine management computer. Or, they may be used in conjunction with a fuel management or stand alone engine management system to control the signals going to the fuel injectors. MAF and MAP systems will typically run in the range of \$1200-2200 range depending on whether they use chips or a fuel management system.

Fuel Management Systems

The main advantage to a fuel control system is that you can make modifications to your car without having to worry about buying another set of chips or getting chips custom mapped. Most of the fuel management systems out there are "piggyback" systems which means that they tap into the existing engine management so that you can manipulate the pulse signals going to the fuel injectors. These are typically used in conjunction with an Air/Fuel ratio meter which you monitor for proper A/F mixtures as you tune the system.

Fuel management systems will typically have some type of control module which can be programmed via dials on the front of the unit or using a laptop computer to manipulate the fuel maps on the chip inside the module. The system may operate with the stock air flow meter, or it may require the installation of a Mass Air Flow (MAF) sensor, or even a Manifold Absolute Pressure (MAP) sensor.

Fuel management systems are generally fairly easy to install and setup. However, they do have limitations with regards to the level of control you have over the signals sent to the injectors and they do not offer any control over ignition timing. And, control over ignition timing is extremely important in ultra-high performance applications. While there are separate ignition control systems available, bear in mind that with separate systems the ignition and fuel systems are working independently of each other. If they are not set up properly, the two systems can actually work against each other.

Stand Alone Engine Management Systems

Stand Alone Engine Management Systems derive their name from the fact that the completely replace the existing engine management system. This means that there is a great deal of work to be done when installing a stand alone system. These system may require replacing engine wiring harness completely and may require replacing most or all of the factory sensors. The obvious disadvantage to this is that it requires a great deal of work to replace existing wiring. You may also have to do some fabrication to use aftermarket sensors with the 944 engine. However, these disadvantages can work to your advantage as well. Since we are installing these systems on cars that are at least 10-15 years old, much of the car's factory wiring harness probably needs replacing anyway. And, aftermarket sensors (most of them typically GM) are normally cheaper than factory sensors.

While a few of the stand alone systems can use the factory crank trigger signal pickup, most will require a crankshaft trigger wheel and sensor be mounted on the front of the engine. This presents problems with regards to sensor mounting and pulley arrangement. However, isn't like you're blazing a trail because someone else has already addressed these issues and can provide you with a solution.

The primary advantage of stand alone systems is that you get complete control over the ignition and fuel maps in one location so that the system can operate as a single unit. Which means that no matter what modifications you make in the future, you'll be able to reprogram the system to compensate for the change in your setup. In addition to both fuel and ignition control, many of the stand alone systems use direct fire ignition via coil packs. This allows you to completely do away with the distributor and provide a more reliable spark to the engine. Other features which may be available with a stand alone system are: data logging, knock control, boost control, NOS control, and even engine cooling fan control. Additionally, with the use of a cam trigger in addition to the crank trigger, you can go to a true sequential fuel injection.

The biggest disadvantage to stand alone systems is cost. Be prepared to spend \$2500-3500 USD for a decent system and really high end stuff can run well over \$8000 USD. For the most part, however, the less expensive systems will do as much or more than the expensive systems. Another disadvantage to stand alone systems is the installation and setup. It can take a great deal of time to install, learn how to use, and properly setup a stand alone system.

Turbochargers

In the early days of performance modifications about the first thing to become popular was changing to different computer chips. Shortly thereafter, the holy grail of horsepower improvement became bigger turbochargers. That philosophy was brought about in part by Porsche itself when it changed from a K26-6 turbocharger on the early 951s to a K26-8 on the later cars. After that, folks figured that they could achieve progressively greater performance by installing progressively larger turbochargers. It didn't take long for folks to figure out (myself included) that for peak performance the turbocharger must be matched to your existing air flow capabilities with a fuel management system (either remapped chips or a different management system) that is setup to provide the correct amount of fuel for your engine and turbocharger. If your engine can not provide enough air flow or even provides too much air flow for your turbocharger, it will not be operating at peak efficiency and performance will suffer dramatically.

I installed a K27-8 turbocharger on my 2.5L 944 Turbo in 1994. I was so disappointed, that I almost pulled it off and threw it in the trash. There was no noticeable improvement in performance and the increase in turbo lag was, in my opinion, completely unacceptable. Fortunately, when I later increased the engine's displacement to 2.8L, the turbo appears to be an almost perfect match. However, the fact that it does seem to be such a good match is more chance than anything else. With everything else remaining stock (i.e. displacement, cylinder head, intercooler), choosing a different turbocharger is much easier. Since the stock air flow rate capability of the stock 2.5L engine is fairly fixed, matching a turbocharger to that flow rate capability is more exacting. However, when you start changing displacement, going to higher flow rate heads, or bigger intercoolers, selecting a turbocharger becomes more hit or miss.

If you have made a displacement change, changed to a different flow rate head, or installed a larger intercooler, provide all that information to your turbocharger supplier. Ideally, if you've changed to a different head, the head will have been bench flowed and those flow rate numbers provide to you with the purchase of the head. Try to select a turbocharger supplier who has a great deal of experience with providing different turbos for different combinations of engine displacement and head flow rates. Your chances of getting a better matched turbo will improve. Also, if you're using the stock engine management system make sure (up front) that your turbo supplier can also provide you with a set of chips mapped specifically for your new setup. If you're using a fuel management system or stand alone engine management system this isn't of concern as you can re-tune your system as necessary.

Adjustable Fuel Pressure Regulators

For low end applications where you are perhaps running a set of aftermarket chips, a different turbocharger, and boost up to about 15 psi, installing an adjustable fuel pressure regulator is, for the most part, a waste of money. The only reason for going to an adjustable fuel pressure regulator is when you're trying to make bigger horsepower numbers with stock injectors and they simply won't flow enough fuel with the lower differential pressure across the injector. If that is the case, you should be using the adjustable FPR in conjunction with a set of chips that are mapped for the fuel pressure you're running. For example some chip manufacturers may have you install an adjustable fuel pressure regulator along with their chips and adjust the base fuel pressure for 44 psi as opposed to the stock 36 psi. In my particular case, running a MAF system with a maximum boost pressure set at 18 psi, the vendor that supplied the MAF and the chips that came with it specified running the base fuel pressure at 52 psi with stock injectors. What I'm saying here is don't go out and simply plunk down your hard earned money on an adjustable FPR alone and expect it to do anything for you. If you do so, it must be for the express purpose of setting a specific fuel pressure for a specific application.

Fuel Injectors

Another common misconception floating around is that improved performance can be obtained by simply installing a bigger set of injectors. Not only is that incorrect but, you can also damage your DME computer in the process.

There are basically two types of injectors on the market, high impedance injectors (with resistances typically greater than 10 ohms) and low impedance injectors which NORMALLY have resistances in the 2-3 ohm range. High impedance injectors are referred to as saturation injectors and low impedance injectors are called peak and hold injectors. The stock engine management computer uses two injector drivers with the two injectors batch fired (both fire at the same time). If you try to use injectors of a different resistance than what the injector driver is designed for, it can cause the injector driver to shut down or even burn up. Now, all 944s use low impedance peak and hold injectors. However, the 944 Turbo uses and injector with a resistance of 4.5 ohms (spec is 3.5 to 5.5 ohms). So, how many low impedance injectors do you think there are with a

resistance of 4.5 ohms (Other than the ones used in the 944 Turbo)? If you guess somewhere around none, you're absolutely correct. So, what must we do to run bigger injectors? Well, we have to do some impedance matching. That's really just a fancy term for making a resistor of a different resistance than the one you currently have appear like it has the same resistance. For example, since most low impedance injectors come in the 2-3 ohm range, we need to make two 2-3 ohm injectors wired in parallel look like two 4.5 ohm injectors wired in parallel (remember two injectors batch fired off of each injector driver). I won't go into the theory behind series and parallel resistance circuits but, to the injector driver, two 4.5 ohm injectors wired in parallel to the driver provides and equivalent resistance to the driver of 2.25 ohms (press the "I believe" button now). Now, let's say we want to install bigger injectors with have a resistance of 1.25 ohms. So, to get up to the 2.25 ohms resistance the driver is happy with, we need to install a single 1 ohm resistor in series (commonly referred to as a ballast resistor) with the two parallel wired 2.5 ohm injectors.

Now that I've gone through that long and boring explanation, I'll tell you that there are plenty of aftermarket suppliers out there who have already done all the calculations and will supply you with a set of bigger injectors and the appropriate ballast resistors to impedance match them to the stock DME injector drivers. Hope I didn't make you mad by making you sit through that explanation. However, it's my opinion that the more information you have, the more understanding you have about how your car works. With greater understanding comes better decision making when it comes to selecting equipment for performance modifications (as I climb slowly down off my soap box).

Once again, bigger injectors are of little use unless you have a set of chips which are mapped based on the bigger injector capability or a tuneable fuel management system.

By now you should be seeing a recurring theme here. That being, if you are to continue down the evil path of performance modifications, it is in the best interest of your sanity and pocket book to install a fuel management or stand alone engine management system early on in the game.

Increasing Engine Displacement

This section on increasing engine displacement is the sole reason I decided to write this document on 951 performance modifications. There is so much misunderstanding and misinformation floating around about increasing engine displacement, I thought it was time to put out as much information on the subject as possible so that folks will be able to make informed decisions with regards to increasing displacement.

There are several ways to go about increasing engine displacement on a 944 and none of them are cheap. You can increase the bore and keep the same stroke, you can increase the stroke and keep the same bore, or you can increase both the bore and the stroke (insert Tim Allen grunt here). Bottom line is, if you plan to do an increase in displacement,

you'd better have very deep pockets or plan to purchase components over a long period of time to spread out the cost (as I did).

I don't know who originally came up with the idea of increasing the displacement of a 944 Turbo but, early on, the only company out there offering anything was Andial. The were one of if not the first companies to offer a stroker kit for the 951. It consisted of a new 3.0L 944 S2 crankshaft, Carillo rods, and Mahle pistons which were custom made for Andial specifically for this applications. The price tag for the kit used to run somewhere in the neighborhood of \$5500 USD with over \$3000 USD for a new crankshaft from Porsche. One of the questions I always get asked about stroker kits is, "hey, is all that stuff required"? Well, to do a stroker kit, you obviously need the 3.0L crankshaft to give you the increased stroke. However, there's nothing that says you have to use a new crankshaft. When I did my stroker engine, I bought the pistons and rods from Andial and shopped around until I found a used crankshaft (\$1100 USD). Now days, you can pick up a used crankshaft for \$1200-1500 USD. I can't tell you how much the pistons and rods are going for today but, in 1996 the Mahle pistons were approximately \$1250 and the Carillo rods about \$950. The pistons are a requirement because you need a higher wrist pin location to provide valve/cylinder head clearance at TDC with the increase in stroke. The Mahle pistons are specially coated with iron to be compatible with the stock silicon impregnated alloy cylinder walls. They also have a set of moly rings which are also compatible with the alloy surface. The rods are not strictly required. However, if you stick with the factory connecting rods the sides of the main bearing saddles on the block have to be machined. The stock connecting rods have a very tall shoulder for the rod bolt. With the increase in stroke, the shoulder will come in contact with a lip on the side of the bearing saddle. So, the excess material has to be machined away to provide enough clearance. This isn't really a big deal as it's what Porsche had to do when they built the 3.0L S2 engine anyway. However, it's going to cost somewhere in the neighborhood of \$400-500 to have the block machined. The Carillo rods have a lower rod bolt shoulder, so they do not require the block to be machined and they are lighter and stronger than the factory connecting rod. I debated about whether to use the factory rod and ultimately decided to go with the stronger aftermarket rod.

Now days, there are many places that are offering stroker kits for 944 Turbos. The primary difference between most of these kits and the Andial kit is that they require the cylinder to be bored and a cast iron sleeve installed. Then, you can use a custom piston which does not require special coatings or special rings. J&E and Cunningham are the leading manufacturers producing custom pistons for these applications. It will cost you a little more to have the cylinders bored and sleeved but, the cost of the pistons is less so, the ultimate cost is about the same. One advantage to sleeving is that it allows the cylinder to hold up much better in the event of a catastrophic failure (i.e. a ring breaks). It also allows you to get a custom made piston in just about any size you want if you want to increase the bore. As far as I'm aware, the Mahle pistons are only available in 100 mm and 100.05 mm diameters. We'll discuss what displacements are achieved with different combinations of bore and stroke a little later.

Another method of increasing displacement is to increase the bore and keeping the same stroke. This is typically less expensive than stroking an engine because it doesn't require you to buy a 3.0L crankshaft. Also, bored engines tend to develop more torque than stroked engines of similar displacement. However, I've never been a huge fan of boring the 2.5L block. The reason being that the cylinder walls on the 2.5L block aren't all that thick to begin with. And the 2.5L cylinders are free standing in the block which means they are unsupported at the top. When you overbore the block for a displacement increase, cylinder walls get very thin and even with cast iron sleeves, the cylinders are weakened to the point that they have been known to move at extremely high loads. And when the cylinders start moving, you start blowing head gaskets. For over bore applications, the 3.0L block is a much better candidate for boring. The cylinder walls are much beefier than the 2.5L block to begin with and the cylinders are tied together at the top with webbing for additional support.

Then of course if you want to go to a really large displacement engine, you can go to an engine that is bored and stroked. Again, the 3.0L block is a much better candidate for this type of displacement increase.

So, let's talk actual numbers. The bore and stroke of the 2.5L engine is 100 mm x 78.9 mm. If you calculate the numbers, the actual displacement is 2.479L. For the 3.0L engine (Bore = 104 mm, Stroke = 87.8 mm), the actual displacement is 2.983L. Now, if we install a 3.0L crankshaft into a standard bore 2.5L engine, we increase the displacement to 2.758L. This is what we typically refer to as the 2.8L stroker engine. If we bore and sleeve the engine to 104 mm (standard 3.0L bore) and keep the 2.5L crankshaft, we increase the displacement to 2.680L (commonly referred to as a 2.7L). I have seen the 2.5L engine bored and sleeved to as much as 106 mm which with a 2.5L crankshaft yields a displacement of 2.785L. This is actually a slight increase in displacement over what most stroker kits provide in displacement. However, over the long haul it isn't nearly as reliable.

For displacements larger than 3.0L, the 3.0L 944 S2 or 968 block should be used as a starting point. However, using the 3.0L block does pose some problems. The biggest problem has to do with the cylinder head. The 944 Turbo cylinder head will not mate up to the 3.0L block due to the difference in cooling passages at the front of the cylinder head. There are several possible solutions to this problem.

First, you can have the 944 Turbo cylinder head modified so that it will mate directly to the 3.0L block. This involves welding a boss on to the cooling passage at the front of the head and then machining a new cooling passage to mate up with the 3.0L block. There are several 944 performance shops who are doing this and I have yet to hear anything negative about going this route. However, bear in mind that there aren't a lot of people out there doing 3.0L+ engines in 944s. The cost for modifying the 944 Turbo head is about \$350.

The next option is to obtain a cylinder head from a normally aspirated 1989 944. This was a 2.7L engine that was only made by Porsche for one model year and the 2.7L engines are somewhat rare. Most of the normally aspirated cars produced in 1989 were the 3.0L 944 S2 engines which utilized a 16V head. The 2.7L engine used the same block as the S2 engine but, used and 8V head and the 2.5L crankshaft. So, the 2.7L head will mate directly to the 3.0L block without modification. However, you will need to swap to a high temperature exhaust valve similar to the one used in the 951 head.

The final, and by far most costly option, is to use the 3.0L 16V cylinder head. Again this will require changing to a high temperature exhaust valve which in this case will have to be custom made. You'll also need to custom fabricate intake and exhaust manifolds to match up to the 16V head. On the intake you can take an intake from a 944 S2 or 968, cut the flange off which mates to the cylinder head and weld it onto a 944 Turbo intake manifold. As you might imagine, all this can run up the price tag very quickly. However, the 16V head is capable of a lot more flow than the 8V head so, if you're planning on an extremely high horsepower application and you're willing to spend the bucks, the 16V head is worth consideration.

A number of folks have asked me about simply turbocharging a normally aspirated 3.0L engine. Aside from needing to swap to a high temperature exhaust valves, you'll also need to do something to reduce the compression ratio down to a level that is acceptable for a turbocharged engine (ideally less than 8.5:1). This means that you'll also have to swap to a custom made piston. However, there is no one currently making a 3.0L piston that is compatible with the stock alloy bore. Again, you have several options: 1) Have someone make a custom set of pistons and send them out to be specially coated and obtain the proper rings for compatibility, OR 2) Have the block bored and sleeved and obtain a set of custom pistons which do not require coating.

So much for displacement increases. Let's move on to something else.

Wastegates and Boost Controllers

Over time, the spring in the factory wastegate will weaken causing the gate to leak by thus preventing the engine from developing maximum boost. You can replace the factory wastegate with a new wastegate from Porsche. However, a new wastegate is brutally expensive. You can also install shims between the wastegate diaphragm and valve body. This will preload the spring and restore it back close to the original closing force (or greater depending on the number and thickness of shims installed). However, this is really only a band aid fix. Finally, you can replace the wastegate with an aftermarket replacement wastegate.

The only problem with aftermarket wastegates is that in most cases they are not a direct bolt-in. The only direct bolt-in replacement (Lindsey Racing) uses a factory wastegate valve body with a different diaphragm (which provides for single or dual-port operation). The Lindsey wastegate requires that you exchange your factory wastegate and that your exchange wastegate be in rebuildable condition. Otherwise a core charge applies. Other wastegates that are being used are Deltas and Tials. The Delta gates are generally less expensive than the Tial wastegates. However, the Tial gates seem to be a lot more reliable. Again, most factory wastegates are not direct bolt-in items. They may require custom flange fabrication and some welding to install. However, some of the performance shops offer packages which include everything to make the aftermarket gate a direct bolt-in. So, when purchasing an aftermarket wastegate, make sure you ask what has to be done to install the gate and if they offer an installation kit.

With regards to boost controllers there are basically two types: manual or electronic. Manual boost controllers can be installed under the hood or may be plumbed through the firewall to provide cockpit control. Electronic boost controllers typically have a solenoid valve mounted in the engine compartment to control the opening pressure going to the wastegate. They will have a wiring harness going from the solenoid to the electronic control box which is normally mounted in the passenger's compartment.

With regards to advantages and disadvantages, electronic boost controllers are supposed to be more accurate and provide better repeatability at the set boost pressure. I can't confirm or deny that. I'm only repeating what I've heard from others. Manual boost controllers are much less expensive than electronic controllers. Electronic controllers will run in the \$350-600 USD price range while a good manual boost controller will run less than \$100 USD. Quite honestly, I think manual boost controllers are a lot easier to install and set up as well. I currently have an electronic boost controller and am seriously considering a swap to a manual boost controller.

Oiling System

944s have long been notorious for experiencing oiling problems with the #2 rod bearing, particularly during hard cornering. There has been a lot of conjecture over the years as to what exactly causes this problem and most of the reasoning seems plausible. In all likelihood there is no single cause of the problem but, is probably a combination of a number of these factors.

One of the factors attributed to the problem is the shear size of the 944 oil pan. It is very large across the bottom and in hard cornering the oil is forced to one side of the pan which can cause the oil pickup tube to become uncovered.

Another theory that has been postulated is that windage from the crankshaft and pistons as they rotate inside the engine cause foaming of the oil inside the pan causing the oil pickup tube to become uncovered. Additionally, it has been suggested that the rotation of the pistons up and down cause pressure waves in the oil in the pan which could cause the oil pickup to become uncovered.

There are a number of solutions which are being used but, it's not really clear just how effective they are. The simplest and least costly fix is to simply run the oil level at or slight above the high level mark on the dipstick. Most folks say running 1/2 quart high is

a good idea especially when running the car on the track. Even if you perform the other modifications for this problem, it's still probably a good idea.

One of the primary fixes for this problem is to drill an additional oil passage in the crankshaft rod journal. The simplest way to do this is to simply drill straight through the existing passage to the other side of the crankshaft. This is referred to as "cross-drilling". Another method is do drill another passage in the rod journal at a 90° angle to the original passage. This is referred to as "perp" (perpendicular) drilling. Of the two, perp drilling is a little more difficult. However, it is also supposed to be more effective. I can't comment one way or the other on that.

Another modifications for the problem is to rebaffle the oil pan. Most places will charge you upwards of \$250 for this modifications including exchanging your old pan. However, this modification is something that a good machinist can do for you much cheaper. Part of the modification involves installing a barn door on one side of the pan. It consists of a piano hinge and a piece of sheet aluminum to form the door. The door is mounted to swing out toward the center of the pan such that in a hard corner the door closes to impede the flow of oil the large open area on that side of the pan. The door is fabricated such that when it is closed there is a small gap between the door and the bottom of pan. The other modification is made to the oil pickup tube. At the bottom of the tube is a screen to prevent debris from being picked up by the oil pump. The screen has almost a half moon shape to it which means that the actual pickup point is close to 1" off the bottom of the pan. The modification involve welding a metal band around the circumference of the screen about 3/4" wide which effective lowers the pickup point.

Another modification used to alleviate this problem is to drill passages in the main bearing saddles. This is supposed to allow free air flow between the saddles thus reducing the pressure wave effect caused by the pistons moving up and down.

On modification that has been used for years in other engine applications is to knife-edge the crankshaft. This acts to reduce foaming of oil in the pan.

The last modification I'm aware of for this problem is the installation of an Accusump system. This system consists of a canister with a pressurized volume of oil. If a loss of oil pressure is sensed, the system will provide pressurized oil to the bearings. Many of the owners I've talked to who have this system feel like it is a waste of money and that the delay time associated with the oil being supplied to the bearings is too great to provide adequate protection.

Crankshaft and Flywheel

If you reduce the rotating mass of the engine, it will spin up much more quickly. One of the things you can do to accomplish this is to lighten the crankshaft. I've known of places that take as much as 17 lbs. off of the crankshaft. However, when you take too much weight off the crankshaft the engine has a tendency to stall when it is running and drops back to an idle condition. I don't recommend reducing the crankshaft weight by more

than 10 lbs. As we mentioned in the previous section, knife-edging the crankshaft is used to prevent foaming the oil in the pan. However, it has the additional advantage of reducing the rotating mass and reducing the windage losses inside the engine.

Another method of reducing the engine's rotating mass is to use a lighter flywheel. This can be done by machining the factory flywheel to reduce the weight or by using an aluminum flywheel. Lightening a factory flywheel will normally run around \$200 USD while an aluminum flywheel will normally cost \$500-600 USD.

Cat Bypass Pipes

Let's start off with an obligatory disclaimer. Strictly speaking cat bypass pipes are illegal from an emissions standpoint. They should only be used for "track only" cars that are not registered for street use. However, I can tell you that a cat bypass pipe will provide a noticeable improvement in performance. By reducing the backpressure on the discharge of the turbocharger, it reduces the turbo spool up time and thus the turbo lag.

<u>Summary</u>

There are a number of other modifications related to engine performance available. They range from improved intake manifolds, cylinder heads with larger intake and exhaust valves, larger exhaust systems, better flowing intercooler pipes, and bigger intercoolers. As I have more time to work on this document down the road I will probably address more of these. Bottom line is you can spend about as much money on performance modifications as your wallet will allow. Choose them wisely.

Drive it like you stole it.