

Making Your 700 or 900 Volvo Go *Fast!*

Staged Engine Modifications to the Turbocharged B23 and B230 Motors.

Introduction

The goal of this section is to present performance enhancement options for turbocharged B23 and B230 engines that will not unduly sacrifice their inherent reliability, and that will also maintain a



high degree of streetability for normal passenger car applications. The performance enhancements will be introduced in **Stages**, an approach that allows the owner to decide just how far he wishes to go -- or how much money he wishes to spend. It probably bears mentioning at this point: performance modifications can be *expensive*, thus I will provide cost estimates associated with the completion of each stage.

The topics here are limited primarily to 1983-1993 Volvo 700s and 940s with B23 or B230 4-cylinder engines. The 960 Volvos have the B3024F engine, an inline 6 cylinder, and are not discussed. The 1990s 700-series and 940s have more sophisticated fuel injection systems and smaller turbos than the 1980s 700-series cars. Some late 1980s 700-series cars got the smaller turbos as well. These differences do not necessarily represent a hindrance to mild performance enhancements. In fact, the later model Motronic fuel injection systems seem to handle performance increases quite well. But the smaller Garrett T28 or Mitsubishi TD05 turbos, while offering faster spool-ups than the Garrett T3s found on the earlier cars, tend to reach maximum effective efficiency at somewhat lower overall boost pressures than their earlier counterparts. Nonetheless, all models from late 1989 on have the strong B230 engine, and as a result accept high performance enhancements very well.

In the following discussions, you will see my references to B23FT and B230FT motors primarily. I am aware of the B23ET and B230ET and B200FT, etc., but since I live in the United States, I am discussing the motors that I am most likely to encounter. Please adjust these comments as necessary to have them apply to your individual variant.

B23FT and B230FT Engines -- an Overview

The first turbocharged 700-series cars used the B23FT engine. Beginning with the 1985 model year, 740/760 turbos began appearing with the B230FT engine. This engine was made in at least three versions, early, transitional, and late. The early version was produced from 1985 to mid-year 1988. The transitional engine, often referred to as the "K" model, was produced from mid-year 1988 until approximately the middle of the 1989 model year. This engine can be identified easily by looking at the engine block. On the left side of the engine, toward the front, and just below the cylinder head, is the block's serial number. If the engine is a "K", just below the serial number and to the right will be an embossed "K." The latest, and strongest of the three B230 variants first began appearing in late-1989 year model Volvos. It does not have any distinguishing markings, the way the "K motor" does, but one can be reasonably certain that one has this late model version by verifying the car or engine's date of manufacture. Obviously, the engine manufacture date will be a more reliable indicator. This date code can be found on the right side of the head, behind the number 4 exhaust port. You will see three two-digit numbers inside of three vertically aligned circles: the top number is the day of the month, the middle number is the month, and the bottom number is the year. I am told there is a date code located on the block as well, but I've been unable to locate it.

B23FT

The B23FT is a motor that responds very well to performance enhancements. It is an inherently stronger motor than the B230 with its forged crankshaft, large main and rod bearing journals, and strong connecting rods. With the right go-fast parts, it can be converted into a scorching performer. The main differences between the B23 and later motors are the B21-style crankshaft and connecting rods, and the distributor location. The B23's distributor is located on the driver's side of the motor, whereas it is located on the rear of the cylinder head facing the firewall on the B230.

The Early, K, and Late B230FT Motors and their Differences

- **Early B230FT:** The early B230FT has garnered a somewhat undeserved reputation as being a fragile motor. True, of the four engine designs available in the 700-series cars, it is the weakest -- but it is still a rugged and reliable motor. There are a number of folks who have gotten 250+ reliable horsepower out of these power plants.

The important thing to know is where the weaknesses lie, and how to avoid having them come into play. The primary weaknesses of the early B230 are

connecting rod design and crankshaft design.

The early B230's connecting rods are the biggest concern of the two, and often fail catastrophically when the boost is cranked up where serious detonation begins to occur. The crankshaft's design is a contributing factor to this problem -- the axial bearing is located in the center of the crankshaft, and the "undersized" main bearings contribute to some unwanted flexing. It is pretty clear that crankshaft flex is a contributing factor to connecting rod failures on the early B230s because when a connecting rod goes, it is almost always # 1 that breaks. If connecting rod weakness were the sole cause of the failures, then we would expect to see a random distribution of failures between rods 1 through 4. But we don't, which points to contributing factors, which in this case is some degree of localized flexing of the crank in the vicinity of the number 1 connecting rod. This problem can be ameliorated to a significant degree by replacing the connecting rods with those for a 1989 or later motor (see the comments on these rods below), and by balancing the rods with all other reciprocating components at the time of their replacement.

- **K Motor:** The K motor is best thought of as an early B230 with a couple of improvements. Additional internal webbing was added to boost overall block stiffness. It got a redesigned axial bearing, but it is still located in the same position as that in the early B230. Unfortunately, it still has the same weak connecting rods as is found on the early B230. Thus, if one is contemplating substantial performance enhancements with their K motor, the same advise prescribed above follows here.
- **Late B230:** Volvo went back to much of the earlier tried-and-true design of the B21/B23 when this motor was developed. Not only does it have much stouter connecting rods (13mm at their thinnest cross-section, compared to the earlier motors' 9mm -- a 50% increase), but the crankshaft was also improved substantially. The axial bearing was (re)located to bearing No.5 position -- the same place as is found on the B23. It also has the large, B23-style main bearing journals, which further reduce the possibility of flexing. It retains the narrower rod journals found in the early B230, however, but this has generally not been seen as a problem by the folks who have built up high-output B230FTs.

A Few Words Of Caution to Early B230FT and K Motor Owners:

The earlier B230 designs will maintain their longevity, even under elevated boost conditions, as long as detonation is avoided. People get into trouble with these engines when they turn up the boost too high and detonation sets in. While blown head gaskets and melted pistons can happen to anybody, one common mode of

failure for these engines is the connecting rods coming apart, resulting in all sorts of nasty and terminal engine damage. Thus, detonation must be absolutely and scrupulously avoided. How can one ensure that one's engine is staying out of detonation? Well, there are a number of ways:

- Run 92 or higher grades of gasoline. Buy your gasoline only from reputable suppliers, so you can be reasonably sure you're getting what you pay for. Consider using a fuel conditioner like Liquid Horsepower™.
- Consider installing Evans racing antifreeze/coolant. Because of its superior heat-dissipation properties, it will have the effect of increasing your octane by a couple of points.
- Install a Air/Fuel ratio meter. Under full-throttle acceleration, the mixture should be about 12:1. If it starts leaning out much past this, it's time to lift your foot off the throttle!
- One of the Stage Three mods listed below is the installation of a rising rate fuel pressure regulator. If you're planning to extract some serious horsepower from your engine, you should think seriously about either this option, or auxiliary or oversize fuel injectors.
- One of the Stage Four mods listed below is the installation of a water injection system. This is perhaps the best way to combat detonation under high boost applications, but probably will not be necessary unless you plan to exceed 16 psi of boost.

Performance Enhancements -- Where to Start?

Performance enthusiasts often refer to performance **stages** because they know that the proper sequence in performance modifications is important. We will follow this same approach here. Regardless of where you wish to end up, however, the most important stage is **Stage 0**, which will ensure that you have a solid foundation upon which to build all future enhancements.

Along with each stage of engine modifications, I will include instrumentation recommendations, which are best viewed as safeguards that should not be overlooked or discounted in their importance.

Stage 0: 160 BHP

The first thing you need to do is ensure that your car is performing properly in its stock configuration. Thus, Stage 0 is actually a maintenance stage, but is an absolutely critical one that mustn't be overlooked or discounted. Following are some of the recommended Stage 0 maintenance steps.

- Check your engine compression. *Do this first.* If your engine's cylinders are

not within the recommended range, stop. Do not pass go. You have a sick engine, and you'll need to correct this imbalance before advancing any further. Correcting the problem can involve anything from changing the head gasket, to a valve job, to replacing the rings -- most likely, it will involve *all* of the above.

- Check/change your fuel filter. Unless you know for certain how long it's been since the fuel filter was changed, and it's still well within its service life, just plan on changing it.
- Check your fuel injectors for flow. Make sure they're balanced, the spray pattern is good, and that they're putting out the amounts they're supposed to. If they flunk any of these tests, you can send them out to services that specialize in balancing and cleaning injectors. Some offer 24-hour turn-around service. Typical charge for the service is \$25/injector.
- If it's been close to 50k miles since the last time you replaced your timing belt, don't wait. Do it now. Replace the idler pulley while you're at it.
- How's your O2 sensor? If you have a high-impedence multimeter, you can check it for voltage. It should fluctuate between 0.1 and 1 volts. If it's stuck at either extreme, it's junk. If you don't have a multimeter, try disconnecting the O2 sensor. If the engine rpm increases or the idle smooths out, the O2 sensor's bad.
- Replace your existing carbon core plug wires with a good set of RF-suppression solid core wires. If you haven't replaced your distributor cap and/or rotor lately, replace them too. May as well buy a set of plugs while you're at it. Lots of Volvo people seem to prefer NGKs over Bosch. I've always preferred Autolites, myself.
- *Check your motor mounts!* If they look old and cracked, they're not gonna last long once you start adding to your engine's output. May as well replace them.
- Flush your cooling system and change your coolant: The Evans stuff is supposed to work very well -- equivalent to increasing the octane level of your fuel by a couple of points because your engine is much less likely to ping.
- Inspect all belts and hoses while you're at it *including the turbo and vacuum hoses*. Replace any that are suspect. It's a good idea just to replace the hose (s) that feed charge air to the wastegate actuator, simply for the sake of your engine's safety. If a leak develops here, you'll experience runaway boost, and the engine can self-destruct in a split-second.
- Check your turbocharger's baseline boost. Adjust if necessary. Factory spec is between 7.5 and 8 psi. It is best not to raise your baseline boost for now. We will be discussing other modifications that will allow you to run higher boost without having to affect the turbo's baseline.
- Seriously consider upgrading to the iPd 3-core metal radiator if you haven't already done so. It's somewhat pricey, but it has the added cooling capacity that your engine will need.
- Bite the bullet, and plan on running Mobil 1 motor oil or equivalent from here on out. At the higher temps your engine will see, the Mobil 1 will remain

viscous when non-synthetic oils begin to coke up. There is some [disagreement](#), however, over whether or not one should switch to synthetic motor oil in an engine that already has a considerable number of miles on the clock. Depending on the level of mods you intend to go with, bite the other bullet and plan on running at least 92 octane from here on out, too.

- Inspect and replace, if necessary, the oil lines going to and from the turbo. These have a tendency to become clogged with oil residue, and will restrict the proper flow of oil through the turbo.

Stage 1: Estimated 190 to 210 BHP

Estimated range of costs to complete this stage: \$400 - 750.

- **Low-Restriction Cat-Back Exhaust**
- **Boost Enhancement**
- **Calibrated Boost Gauge**

For many people, Stage 1 modifications are enough. This is because this first set of modifications will generally result in quite noticeable performance improvements, typically ranging from 30 to 50 bhp, and because it is relatively easy to do. For example, after completing Stage 1 except for the calibrated boost gauge my 745T was producing 190 crankshaft horsepower -- 30 hp over stock (mods were a hi-flow cat-back exhaust system and the Saab APC with NO boost increase above where it was already set). Lacking the calibrated boost gauge, I estimate the APC's boost level was set to between 12 and 13 psi. 190 hp may not seem like a lot to many people, but I can assure you, it made for one quick brick. Even at this relatively low level of output, a 190hp 745T is quicker than most other cars on the road.

Low-Restriction Exhaust: Generally speaking, when it comes to turbocharged engines and low-restriction exhaust systems, bigger is better. The practical upper limit for exhaust tubing on 700 Volvos is 3" diameter. For all applications but the most extreme, however, a 2.5" exhaust pipe diameter will more than suffice. For this first stage, then, the best modification will be to replace the existing exhaust system from the catalytic converter rearward with a low-restriction, high-performance "cat-back" system. You'll want a setup that eliminates the 1st muffler or resonator and has a mandrel bent pipe from the catalytic converter to the rear-mounted muffler. Popular choices for the rear muffler include Dynomax, Borla, and others. (I'm waiting for somebody to try out the PowerTone negative backflow muffler and give us a report on it.) For an exhaust tip, I prefer a straight pipe as opposed to the "S"-shaped stock tailpipe -- it's a little less restrictive and, to me, looks better.

Boost Enhancement: There are a number of paths one can take to increase

boost levels, some more risky and more expensive than others. The most economical means involves teeing an aquarium air supply regulator valve (available at most pet stores) into the line running between the turbo outlet and the wastegate actuator. When the valve is opened, the actuator is "fooled" into thinking that the boost level is lower than it really is, since the excess pressure that would cause the actuator to open the wastegate is being bled through the partially open valve. *Use with caution!* The best way to use a manual waste-gate control is to advance it until the engine begins to ping, and then back it down a notch or two. Resist the temptation to crank it all the way up and leave it there. A blown head gasket, a melted piston, or a rod through the side of the block will be the likely result if you do. The **HKS EVC** is an electronically controlled boost controller that uses this self-same principle: instead of a knob to crank, the user presets the desired boost levels into the electronic controller. The **Saab APC** is an electronic turbo boost control system found on 900 and 9000 Saab turbos, but which can be easily adapted to work on turbo Volvos. It is a well-designed, adjustable electronic turbo boost control system that works largely independently of the various other controls on the engine, requiring only three inputs: manifold vacuum/pressure, an rpm signal from the coil, and knock sensor information. A few intrepid Volvo owners, including this writer (well, dunno about the intrepid part, in my case), have installed the APC on their 700-series Volvos. Unlike the aforementioned manual boost controllers, the APC controls boost via its built-in electronic routines, plus if pinging is detected, the APC will back off the boost in 1.5 psi increments. One nice feature of the APC is that the amount of boost is adjustable, so one can adjust it in increments from mild to wild. For more information on how to install the APC on your 700-series Volvo, visit John Bertram's Internet site, [The Volvo APC Project](#). Volvo produced a unit quite similar in operation to the APC, although not nearly as flexible, called **Turbo+**. This unit was available as a dealer-installed option on new cars, and was an expensive one at \$800 or so, but it is good for an additional 20 hp at full throttle acceleration for a handful of seconds above 3,700 rpm. I have one of these on my '88 765T and regard it as being most useful for providing a bit more *oomph* for passing slow traffic on rural highways and interstates.

Install a calibrated boost gauge: The Volvo OEM boost gauge just doesn't cut it. It is uncalibrated, so you have no idea what level of boost you're running. I have looked high and low for a mini gauge that will fit into the stock gauge's location, but have found none so far. Still, one can mount another gauge in a couple of places: either in the center console (if you don't have the E.Q. option installed), or using an A-pillar gauge pod. I prefer the latter because it can be mounted at close to eye level, whereas placement in the center console is not as conducive to close monitoring. [IPd](#) is supposed to be supplying A-Pillar gauge pods now -- or if not at this time, then soon. Another fitment possibility exists: pods designed for 1993 and later Toyota Supras can be adapted to fit. This requires a bit of bending of the pod with the aid of a heat gun, but is not difficult if you are reasonably good with your hands.

Stage 2: Estimated 230 to 260 BHP

Estimated range of costs to complete this stage: \$450 - 600.

- **Performance Camshaft**
- **Adjustable Cam Timing Wheel**
- **Double Valve Springs**
- **Air/Fuel Ratio Gauge**
- **Elevated Boost**

Performance Camshafts: Based on recent reports, I favor the VX, available from either [IPd](#) or [S.A.M.](#), and the Gr-A T5 cam available from [S.A.M.](#) Please visit my [camshaft data](#) page for an in-depth examination of Volvo cams. Based on specs and driver evaluations, the VX cam appears to be the milder and the Gr-A T5 appears to be the wilder of the two. Both are excellent performers, though, and without flowbench or dyno results it would be difficult to say definitively which is best for which application. For general street use, however, low-end performance will be improved by advancing the cam timing a moderate amount.

Adjustable Cam Timing Wheel: At approximately \$140 apiece, these puppies are not particularly cheap, but they sure make the process of dialing in a cam a whole lot more pleasant than the alternative, which is to have a variety of offset keyways cut. But, if cost is a factor for you, you might want to check into the offset keyway option. I would recommend that you start with one that will provide you with 4 degrees of advance, which seems to be sufficient for most performance-oriented Volvo cams.

Double Valve Springs: These can be obtained from Volvo for a reasonable sum. They are especially recommended if you elect to go with the Gr-A T5 cam, since its steep ramp may allow for some valve float at higher rpms if they are not used. Installing them with the head still on the car may be a bit of a trick, however, and to be frank I do not know if it is even possible. I suspect there is a way to accomplish it, though. One way to keep the valves from dropping into the cylinder is, with the spark plug removed, rotate the crank so the piston is a few degrees before TDC on the compression stroke and then feed a section of braided cord or rope into the combustion chamber. Then rotate the crank to bring the piston up to TDC, which will compress the cord against the valves. Then, if you can find a spring compressor tool that will depress the springs sufficiently to remove the keepers, their replacement should be relatively simple.

Air/Fuel Ratio Gauge: By this point, you'll be itching to turn up the wick on the turbo. In the interest of preserving your engine's longevity, however, this temptation should be resisted until you have installed an A/F ratio gauge. They come in a variety of shapes and sizes, but I prefer the round ones that will fit in a standard 2" (52mm) gauge opening. I would also suggest that you place this gauge in a highly visible location -- perhaps the best of which would be on the A-

Pillar, adjacent to the boost gauge discussed above. The A/F ratio gauge is attached to the hot wire coming off your O2 sensor, and is able to determine the engine's air-to-fuel ratio based on the O2 sensor's voltage signal. Stoichiometric is 14.7:1, and is where the LH-Jetronic (or Motronic on some cars) EFI system will attempt to keep things during normal driving. Under load, or full-throttle acceleration, however, the system knows to allow more fuel in to provide additional power. The A/F gauge should indicate a ratio of about 12:1 during times of full boost at wide open throttle.

Elevated Boost: Any temptation to turn up the wick should be resisted until you have installed the A/F ratio gauge discussed immediately above. By doing so, it will allow you to monitor A/F ratios as you dial the boost upward, preferably in small increments. Based on the experience of several 700-series owners I have talked to and corresponded with, safe boost levels of as much as 15 psi should be possible without any fuel system modifications. 15 psi is also close to the upper limit of the turbo's useable operating range before it will begin to superheat the charge air. In any event, to be absolutely on the safe side, you will want to monitor your own engine's fuel delivery capacity for yourself, which is why any foray beyond the fuel-cutoff switch's engagement point should be well instrumented.

Speaking of that switch, it is factory set to about 13.5 psi, although it is supposed to be adjustable if you can manage to dig out the glue that is covering the adjustment screw. Obviously, the preferred approach would be to adjust the fuel cutoff point upward to the level at which you know you shouldn't venture beyond, but this will depend upon whether or not you can get to the screw. Most folks wishing to run higher boost levels simply bypass the switch, which is probably not the most prudent thing to do. Another possibility is to use the Saab fuel-cutoff switch. If you've elected to go with the APC system, you might want to pick up this switch along with the rest of the components (on the system I obtained, this switch and a 5-prong relay were located on the same bracket as the pressure transducer). The Saab switch is just a whole lot more complicated than the Volvo's: it has two hose connections compared to the Volvo's one, plus it has *three* adjustment screws, compared to the single Volvo screw, and it has three spade-type electrical connectors. Lest you begin feeling intimidated, if you have a gauged and regulated air supply and a multimeter, you should be able to figure out which does what without too much difficulty. Better take notes, though! Obviously, I have not tried to figure out this switch yet. When I do, or when I hear from somebody who has, I'll include that information here.

Stage 3: Estimated 280 to 320 BHP*

Estimated range of costs to complete this stage: \$1200 - 1800.

- **1990 or Later Exhaust Manifold**

- **Upgraded Turbocharger**
- **Rising Rate Fuel Pressure Regulator**
- **Chip for ECU**

1990 and later exhaust manifold: If your 700 is a 1989 or earlier, you can pick up roughly 10 more horsepower just by changing out your exhaust manifold to a 1990-and-later design. The runners are round instead of square, and the overall design is more conducive to smoother flow, which aids in reducing backpressure. Most, if not all, of these late manifolds that you run across will have an exit port sized to fit the smaller Mitsubishi or Garrett T28 units. If you're replacing a manifold that was originally matched for a Garrett T3, you'll have to have the port opened up. Any machine shop with a mill can do the work for you. **Please Note:** these later manifolds are prone to cracking due to warpage. Before buying one, check first for cracks, but also check for uniform flatness across the exhaust flanges. If the manifold has warped some, as long as it isn't too severe, it can be resurfaced by a machine shop. Most likely, though, this won't be necessary. I bolted down a late-model manifold to my 1987 230FT, one that had a fair amount of warpage. It sealed up nicely, and hasn't shown any evidence of exhaust leaks in over two years of use. Also, without the exhaust manifold support bracket, the bolts holding the turbo in place are reportedly likely to shear off. I believe the likelihood of this occurring can be reduced by using Volvo turbo exhaust studs -- yup, the *expensive* ones -- as a way of avoiding this problem. Still, it's a better idea to install the support bracket with the manifold, so you won't have to worry about this problem.

T04/T3 Hybrid Turbocharger: The T04/T3 setup, based on a Garrett design, is the one most folks who are into performance turbos prefer nowadays. The T04 side is considerably more efficient than the T3, having a flow rate equivalent to T3s running much larger trim sizes and A/Rs. Yet because the T04 accomplishes this higher flow rate with a smaller trim size and A/R than the big T3s, it spools up much faster. The T3 turbine side is used for backward compatibility so the unit can bolt down to the existing manifold, although (depending on whose hybrid you go with) its internals are different, resulting in reduced backpressure and increased flow. Please note: not all T3/T04s are created equal. There is a wide variety of internals, A/Rs, etc, that are available, so exactly whose turbo you go with can really make a big difference as far as output goes.

One of the most interesting recent developments is a T04/T3 that utilizes ceramic ball bearings in the core. Turbonetics originally developed the design to increase turbocharger longevity at very high boost settings. They discovered that a significant side benefit to this design was a much faster spool-up time. The ceramic-bearing-equipped hybrid retails for about \$600 more than its standard equivalent, and represents the edge of the envelope in turbo development applicable to Volvo cars. If you're after ultimate performance, this may be *exactly* what you're looking for.

Rising Rate Fuel Pressure Regulator: A rising rate fuel pressure regulator (rrfpr) is an ingenious device. Your stock fuel pressure regulator operates in a linear 1:1 fashion, which means for each pound of increase in boost pressure, the fuel pressure is increased by one pound. This is essential with turbocharged, fuel-injected engines because the increased manifold pressure that the fuel injector "sees" must be overcome by an equal increase in fuel pressure in order to maintain the same fuel flow. What an rrfpr does is to increase fuel pressure at a proportionally greater rate: for example a 2:1 rrfpr would deliver 2 psi more fuel pressure for every psi increase in boost. The advantage to this is that, as horsepower, and therefore fuel requirements, increase, an rrfpr is better able to stay up with the engine's fuel demands, and thereby prevent overly lean conditions from arising, which can quickly turn a smooth-running engine into a twisted piece of scrap.

The best sort of rrfpr to obtain is one that allows you to adjust fuel rail pressure as well, such as those built by Vortec. One technique that works quite well is to adjust the fuel rail pressure *upward*, so that when the rrfpr begins ramping up the fuel supply, it is doing it at an even higher pressure than normal, allowing an even greater supply of fuel into the engine to meet the fuel demands caused by elevated boost. So that your engine does not run overly rich under normal driving conditions, however, it is probably a good idea to have your CO checked and readjusted, if necessary. Another type of adjustable rrfpr allows the user to adjust the rising rate as well. One I have read about allows for adjustments between ratios of 2:1 and 3:1, with settable starting and end points. This sort of rrfpr, with its variable rate control, will likely be easier to adapt to fuel systems with limited CO adjustment ranges.

Chip for ECU: The biggest problem with the LH2.2 Jetronic system from a performance standpoint is its built-in fuel cut-off rev limiter that kicks in at approximately 6,000 rpm. The B23 and B230 are capable of revving much higher than this, with their strongly overbore configurations. This problem can be taken care of with a chip replacement, but unfortunately the availability of performance chips for LH2.2 Jetronic systems is sketchy. Chips are readily available for some European Motronic systems, and others. In addition to getting rid of the rev-limit, a performance chip remaps the way the system behaves under situations of peak load and can increase the output of a system substantially. Currently, I have very little data on chips for 700-series Volvos. For the European versions and for 940s, one excellent source is [BSR Sportsman](#), located in Sweden. At the time of this writing, the English version of their website is still under construction, but it is still possible to find one's way around on the Swedish side. BSR offers an extensive selection of chips and other mods for Volvos.

** Owners of Early B230s and K motors please note: if you are approaching this level of performance with a **stock bottom end**, chances are that you are reaching the **ragged edge of reliability**. Before completing this stage, it is **strongly advised** that you replace the stock connecting rods in your engine with 1990-spec*

Volvo or custom rods, such as those available from Crower, Carillo, or others.

Stage 4: Estimated 350+ BHP

Estimated range of costs to complete this stage: \$800 - 1200.

- **Oversize or Additional Fuel Injectors**
- **Water Injection**

Oversize or Additional Fuel Injectors: When elevating boost to the levels necessary to achieve well in excess of 300 bhp, it is a sure thing that the stock injectors will have run out of steam. At this point there are basically two options available: oversize injectors, or additional injectors. The advantage to running oversize injectors is both simplicity and economy *if* they are selected and configured properly. The disadvantage to running them is that, if not selected properly, the engine will run rich under normal operating conditions, and they may have less than optimal spray patterns when running at levels below that which they were designed to operate. The advantage to running one or more additional injectors is that they are only switched on when needed, so normal driving is not affected. The disadvantage to running additional injector(s) is that, almost always, an auxiliary control unit is required, resulting in considerable additional expense. Please read my discussion on [Fuel Demand and Supply](#) for more information on this subject.

Water Injection: This option often becomes a necessity if one is chasing very high levels of boost -- say 18 psi or above. Water injection is used primarily to cool the air/fuel charge going into the combustion chamber so that detonation can be avoided. In this function it is without question one of the most effective means available for controlling detonation. A complete H2O injection system should include the injector, its controller, a reservoir tank and all necessary hoses. Best placement for the injector on a B23 or B230 is just upstream of the throttle body on the intercooler-to-throttle-body pipe. This location ensures good mixing and sufficient retention time for the water to absorb as much heat as possible from the fuel/air mixture. The only kind of water that should be introduced into this system is *distilled* water, by the way.

Stage 5: Estimated 350+ BHP

Estimated range of costs to complete this stage: \$1,400 - 2,000.

- **3-Angle (or more) Valve Job**
- **Oversize Exhaust Valves**
- **Port & Polish and/or ExtrudeHone Head**

- **ExtrudeHone Intake and Exhaust Manifolds**

This stage is all about one thing: improving the ease with which your engine breathes. The benefit from completing this stage is that your engine will handle more volume of air/fuel mixture per psi of boost, which means that you'll be making even more horsepower at the same boost level, or that you can turn the boost down and have the engine still produce the same amount of horsepower. I didn't show an increase in horsepower over the previous stage, since it is my personal position that one should opt for reducing boost once this is done, and only raise it again after the next stage is completed. At this point, some of you might be considering installing a 3" exhaust system, custom-built exhaust headers, an external wastegate, etc. Once again, all in the name of improving efficiency. The sky (and your wallet) is the limit!

3-Angle (or more) Valve Job: Most machine shops worth doing business with can perform 3-angle valve jobs nowadays. Some can grind the seats to as many angles as you want. The idea behind a multi-angle valve job is that it reduces the amount of friction experienced by gasses as they enter and exit the combustion chamber, which means they can get in and out *faster*.

Oversize Exhaust Valves: This may or may not be a necessary modification -- it depends largely on the individual. A significant level of efficiency can be found on the exhaust side if this mod is performed, but it is also an expensive one -- easily several hundred dollars all by itself.

Port & Polish and/or ExtrudeHone Head: The ExtrudeHone process, in which an abrasive polymer is forced through a head's ports until they are smooth and free of roughness, is one that attempts to duplicate to a large extent the various and mysterious arcana of porting and polishing. I list both procedures because the ExtrudeHone process is always subtractive and never additive. However, we know that often an optimum flow rate is found by actually adding material in well-chosen areas and removing it in others. Thus it is likely that, once a baseline shape has been established via traditional methods, the ExtrudeHone process would then be able to smooth it into a natural path, most conducive to high flow.

ExtrudeHone Intake and Exhaust Manifolds: Same rationale applies here as is specified above. Extrudehoning the manifolds can result in a substantial increase in flow efficiency.

Stage 6: Estimated 400 BHP and Beyond

Estimated range of costs to complete this stage: \$1,800-2,400

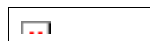
- **Stroker Kit**
- **Align Bore Block**

- **Balance and Blueprinting**

Stage 6 is about two things: bulletproofing your motor's bottom end and increasing displacement. The components are self explanatory. [Topi](#) at TMS Motorsports sells **stroker kits** for normally aspirated Volvos in displacement ranges from 2.5L to 2.9L, although the only difference between his kits and those that would work with a turbo would be the compression ratio of the pistons. He also sells the components individually, so custom pistons could be ordered if he were not able to supply them. It is possible to have all this done yourself as well - - have your crank offset ground by a machine shop that specializes in crankshaft grinding, order custom rods from manufacturers like Crower or Carillo, and have your pistons made by J&E or others, who have the machining equipment where they can one-off stuff for just about any application. **None** of this stuff comes cheap, though. Figure on a stroker kit alone setting you back in the neighborhood of \$1,500.

Regarding the displacement of the kit, personally I would not recommend exceeding much more than 2.5L. Inline 4-cylinder engines, by their nature, tend to shake. When the displacement gets much beyond 2.5L, without benefit of a counterbalance shaft, the shaking can lead to a rather rough driving experience, and potentially shortened life of various components bolted to the engine. Further, from a purely pragmatic standpoint, one should ask oneself, how much does one need? There are a few crazy Swedes who have built up monster 2.5L Volvo motors that put out in excess of 500 horsepower!

When overhauling the bottom end of a motor, especially if it is intended for a performance application, it's more than a good idea to have the block align-bored and all the reciprocating components balanced and everthing blueprinted. This will go a long way toward your future peace of mind when winding the big Volvo 4-banger out tight.



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