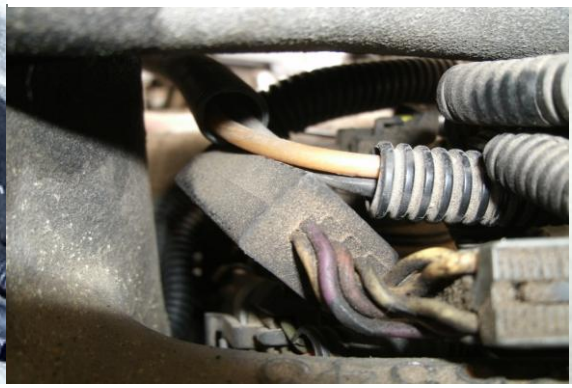
Recommended modifications/maintenance for 94-95 GM 6.5L electronic fuel injection (EFI) diesels, in relative order, by buddy

Much of this information is applicable to older and newer 6.5 diesels. Older mechanical injection trucks can benefit from all but the EFI and PCM info, and newer OBD2 vehicles may ignore the OPS info and PCM upgrade method, and already have pieces of the cooling and air cleaner improvements. This is not a full diagnostics reference; check out helpful online forums. I recommend the real GM Service Manual and Diesel Supplement, GM's "6.5L Diesel Electronic Fuel Injection" training book, or ALLDATAdiy subscription. I have no affiliation with vendors mentioned, other than being a repeat customer to most.

(1) First and foremost, the vehicle needs to be in good working order, set up properly. In order to ensure that it is, a scanner is extremely useful. Engh Motors sells scanner software called GMTDScan Tech that works for 1994 and 1995 OBD1 6.5L diesel engines. Make sure your Injection Pump (IP) is properly timed, calibrated and well lubricated. With the engine at warm idle, make sure the fuel rate is about 8mm^3 and measured timing is very close to desired timing. If the fuel rate is 0-3mm3, you either performed an optic bump or this IP was not calibrated by the rebuilder. Having a low idle fuel rate doesn't actually mean you are using less fuel, just that the Powertrain Control Module (PCM) is confused as to what 1mm^3 of fuel actually means in terms of the pulse width it commands. This can cause poor idle and shifting quality, with loping, fishbites, and an overly sensitive fuel pedal. This can be corrected by repositioning the Optical Sensor (OS) within the IP. Remove a snap ring around the OS connector, remove the IP's top lid, loosen the T-40 screw holding the OS in place, and move the OS towards driver side to increase the commanded fuel rate at idle. An idle fuel rate too high is not that bad, except you might not be able to belch as much black smoke and slightly less top end power. Either condition can also be offset with programming, what I refer to as Optic Bump normalization. On the OS topic, these years had a "black box" electro-magnetic/radio frequency interference filter between the OS and engine harness. Filter degradation often leads to fishbiting or unexplained codes. It is commonly removed with no ill effects, by connecting the engine harness directly to the OS; otherwise there are replacement filters.

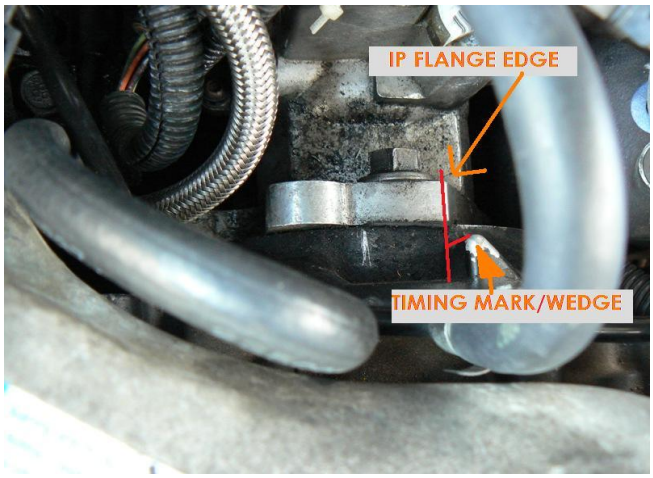
Left: Two parts of OS exposed after removing upper intake and top of IP. The lower OS piece will move side to side after loosening the T-40 bolt shown.
Below: OS filter above the IP, below upper intake plenum, and pictured separately removed from the engine bay.



On every fuel fill-up of #2 ULSD add a lubricant, and not just any off the shelf diesel lubricity additive. Many of the most popular additives (i.e. Power Service) have failed to show any or enough improvement in wear testing or real world for our older DS4 IP. Most are inadequate, only good for #1 LSD fuel or newer systems built for ULSD. B5 fuel is the best option, or simply a gallon of whole biodiesel for 20-30 gallons of ULSD. I do not recommend using higher than 5% biodiesel concentration, such as 5 gallons of

B20 added with 15-20 gallons of ULSD. Simple ash-less, TCW3 2-Cycle oil is an effective additive, one quart for 25-30 gallons of ULSD. Others use Non-Detergent SAE30 motor oil with success, 2 quarts for 25-30 gallons of ULSD. Used motor oil is a bad idea with the DS4 IP, and ineffective as a lubricity additive. On the subject of additives, a cetane improver such as Amsoil Cetane Boost or Red Line RL-3 is a good idea, because the US has low cetane requirements compared to other countries.

You must also ensure the IP is correctly timed, which is not done by just looking at the scanner data, because desired and measured timing can be reporting good values even with the IP in the wrong position. The IP timing procedure results in the PCM storing a Top Dead Center Offset (TDCO) value, which defines how it correlates OS timing signals to Crankshaft Position Sensor (CPS) signals. You don't know that your IP is timed correctly by looking at the reported TDCO value, because it's a value saved in the PCM until the TDCO Learn is initiated with a scanner. The IP, OS, CPS, timing chain, PCM, ect… can be changed and it still has the last value stored in that PCM. This is very common, and to ensure it is timed correctly you must run the TDCO Learn and see if it is within tolerance afterwards. Ideally, I like the value to be between -0.75 and -1.50. Factory timing procedure placed the TDCO value between -0.25 and -0.75, but the PCM's tolerances are from +2.02 to -2.02 before a DTC88 is reported. The TDCO value is not easily understood, but it correlates with a base timing value when the stepper motor is incremented to its most retarded position. The base timing will be seen when commanding Time Set on the scanner before commanding the TDCO Learn. To the right you can see how the IP can be set when installing it before running the timing procedure. The IP flange edge next to the top nut should be slightly towards the driver side of the timing cover wedge.



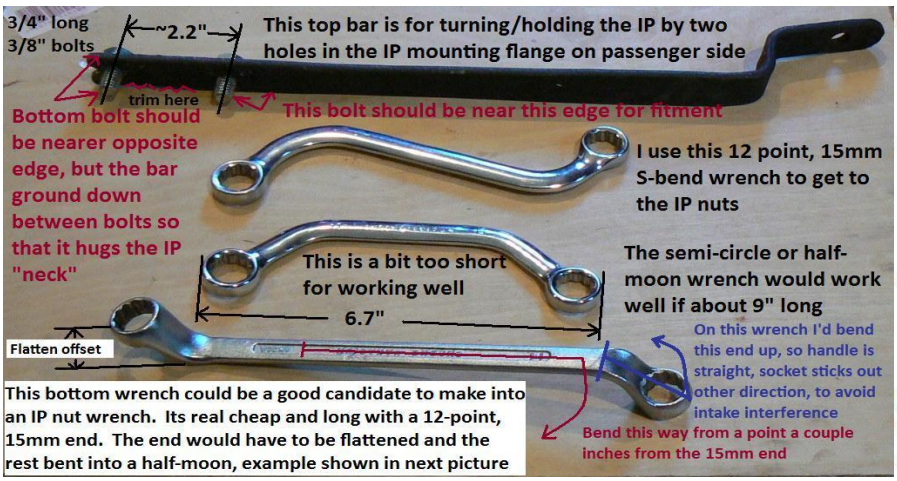
There is a significant power difference between a positive and negative TDCO value, even though it may only be a 1 degree difference in base timing, and the PCM advances the timing to a programmed position regardless. This could be because changing IP position may increase IP housing and transfer pressures when metering fuel, so that the correct volume or more fuel is metered. Although the scanner displays camshaft timing for actual/measured/desired timing, crankshaft timing is simply double the reported value, so 1 cam degree change is 2 crank degrees. When changing TDCO from -0.5 to -1.94 you are changing base timing from 7° to almost 8° crank advance. Some scanners may report "actual injection pump timing", which will be closer to the crankshaft timing when the engine is operating at advance greater than the physical position of the IP. The advance can be less than the physical position of the IP, when the stepper motor retards timing from its nominal position. If you are having an extremely difficult time setting the TDCO or getting strangely low timing advance at idle then it is possible you have improperly installed the CPS out of rotation. That can happen if the mounting tab breaks off, or the tab can pop off some models and put back on 180° wrong.

To time the IP, you will need a few tools and procedures below. This assumes you have the single t-stat housing; with double housings it takes a bit more work for access, but the procedure is the same.

1) The right scanner, GMTDScan Tech, Tech1 or Tech2 (Snap-On scanners display incorrect data)

2) IP nut wrench; A 12-point, 15mm half-moon wrench (~9" long), or an S-bend wrench. There are official IP nut wrenches (Kent-Moore J-41711 and J-41089, or OTC-6087) that cost $100+.

3) A way to turn and stabilize the IP. Turning the IP can be done with a large oil filter or cannon plug pliers that fit around the "neck" of the IP, between it's mounting flange and main body. The official turning wrench is also $100+ (Kent-Moore J-29872-A or OTC-6083). I have used the oil filter pliers, but also made a tool for turning the IP. The tool is pictured below, just a 3/4" to 1" wide, 3/16" to 1/4" thick metal bar with 3/8" threads tapped ~2.2" apart to line up with holes in the IP mounting flange for the official timing tool; 3/4" long 3/8" bolts are threaded in.



a) Warm up the engine over 170F, and with the scanner verify there are no DTCs. If you have a DTC88 for timing/TDCO, clear it before running the "TDCO Learn". If you have other DTCs, such as DTC 17, 18, 19 for the OS or CPS you need to resolve them first.

b) While at normal idle, the lowest idle you have available, nearest to 600rpm, command the "Time Set" to "On" and observe the actual timing value. The value should be approximately 3.5° degrees, while the desired timing is at 0°. The value may jump around a lot, but you want an average value of 3.5° to 3.8°. Command the "Time Set" to "Off" after about 20 seconds. I have found that mine will sometimes go lower after performing the TDCO Learn, so if it's a little high continue anyway. The value you see is your "base timing", where the IP Stepper Motor has incremented as low as possible.

c) Record the current TDCO value, and then Command the "TDCO Learn" to "On" and observe the TDCO value. This will time out after about 20 seconds, or you can command the "TDCO Learn" to "Off" and it should store the value on the screen at the time. Occasionally the value may continue to bounce around after commanding it Off, and time out later. You can run the TDCO Learn again if it moved to an undesired value. Compare to the previous value you recorded to see if your IP was properly timed before. I prefer the TDCO value to be between -0.75 and -1.5. If you are getting -2.02 or +2.02 that is just the limit the scanner displays, will set a DTC88, and you could be quite far out of tolerance. The "Time Set" should give you an idea of how far out you are, if you run it again. A "Time Set" base timing value over 4° will go to -2.02 and any value under about 2.5° will result in a +2.02. If the base timing value is just over 4°, and you are aiming for a TDCO value of -1.94 or thereabouts you can run the "TDCO Learn" again at a higher idle RPM setting or hold the fuel pedal at about 1000rpm. This can get you from -2.02 to -1.85 or -1.94.

d) Up to now you've just verified if your timing was set properly in the past. To modify the TDCO value you need to physically turn the IP on its mount. Always shut the engine off prior to loosening the IP nut(s). To get a less negative value the IP needs to turn towards the passenger side, and more negative turn towards the driver side. With the engine off, scribe a line on the timing cover where the IP is currently set, then loosen the IP nuts with the 12-point, 15mm half-moon or S-bend wrench. The

lower nuts are difficult to get to and have limited space to turn a wrench. It takes some finesse to get the wrench on the nuts, which you'll have to do 2 or 3 times to get the nut loose enough. On the passenger side you may need to unclip the turbo oil supply hose from the coolant crossover and hold it out of the way. Once you get it figured out and done once it gets much simpler. To turn and hold the IP you can use the large oil filter pliers, or a tool you fashion. The IP will provide resistance to turning so you will have to hold it while you tighten the top IP nut. Each millimeter you turn the IP will change the TDCO value by about 0.7. Leave the bottom two nuts loose while you check the TDCO value by repeating steps (a) to (c). Repeat step (d) with just the top nut until you achieve the desired TDCO value.

e) Once you achieve the desired TDCO value then shut the engine off and tighten the lower two IP nuts. Once all IP nuts are tight, I recommend running steps (a) to (c) one more time to verify the IP did not move while tightening the lower nuts, it happens.

The snapshot below from GMTDScan Tech is a typical example of how the IP could be way too "advanced" towards the driver side, so much so that the "base timing" seen in Time Set is 9.3°. It is supposed to be 3.5°, but the PCM has an old stored TDCO value of -0.88 that is within tolerance. When I actually run the TDCO Learn it will set DTC88 and TDCO value will show -2.02. The same concept could happen in a way too "retarded" manner. This would not set any other DTC and could never be noticed without the Time Set or TDCO Learn if the desired timing at idle is over 9.3°. The stepper motor DTC34 for timing is not set until there is more than 5° difference between desired and measured timing. There are some stock programs with as low as 4.5° timing where this situation could be seen just by looking at the scanner, but would still not set a code. If you do have a 4.5° idle timing PCM program this error would probably make the truck much faster off the line, since idle timing between 8° and 11° is a lot more responsive. However, this is not good for general reliability and efficiency. It could be a free performance upgrade for some, but idle timing that advanced is not good with a functional EGR valve.

(2) Remote mounted Fuel Solenoid Driver (FSD), a.k.a. Pump Mounted Driver (PMD), on heatsink, using quality extension cable made in the USA, silver or copper thermal grease between FSD and heatsink, tighten down, and weatherize it with a bead of silicone around the outer edge of FSD. Locate the FSD away from engine heat. FSDs, like any electronics, don't like to be hot, but they also don't like to be very cold. Cycling between cold and hot causes FSD failure, but the solutions center around

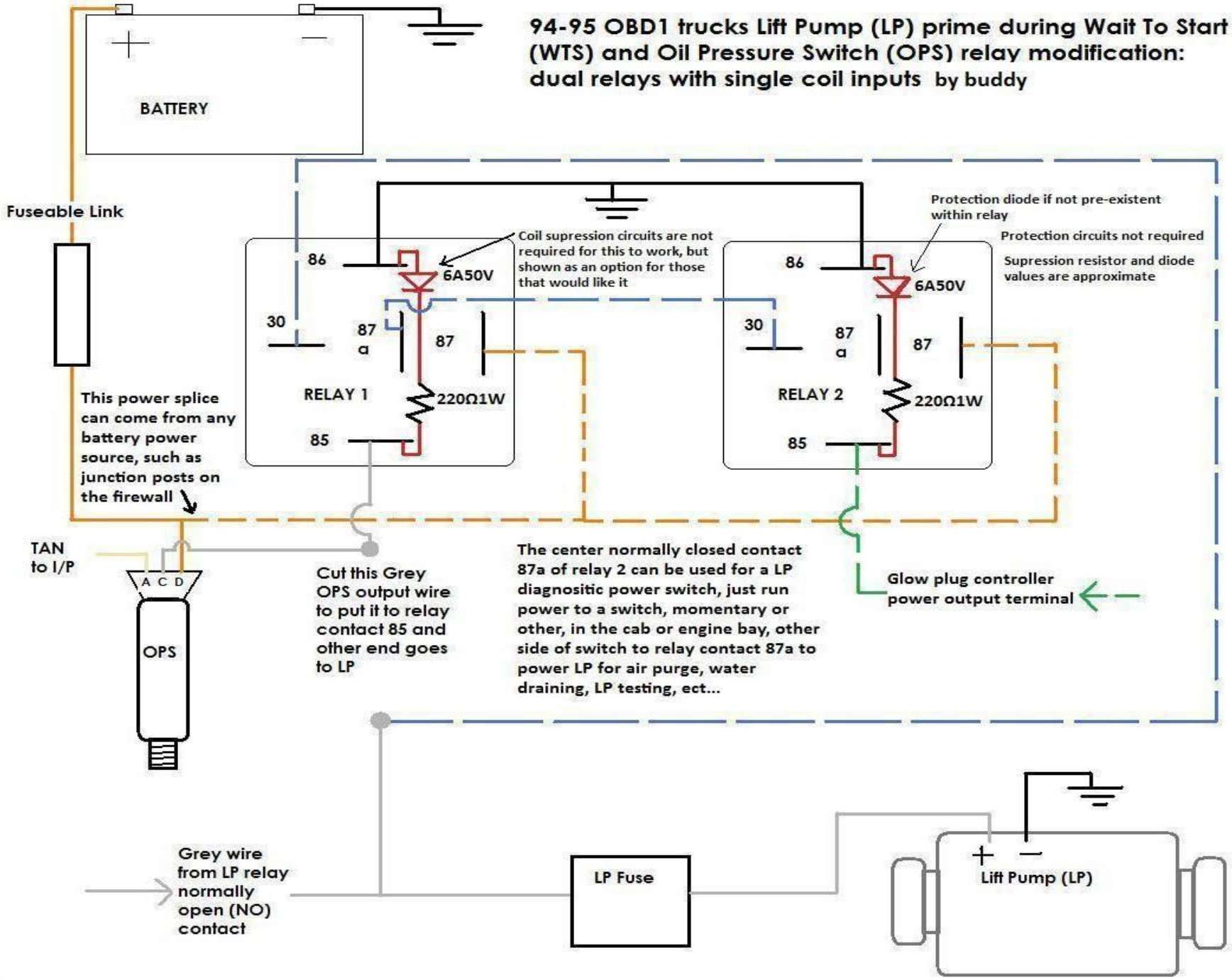
removing heat. People in very cold climates may experience higher failure rates in the winter, when keeping them from freezing would help. The idea is to limit the lower and upper temperature to limit the temperature swings on each warm up and cool down cycle. Leave the existing ground wire attached to the top of the IP. PMDcable.com sells quality 6' PMD cables. When mounting the FSD ensure the heatsink itself is grounded through mounting hardware or by ground strap. Also ensure the FSD has direct continuity to the heatsink, which means no thermal pads that disrupt electrical continuity. There is thermal grease that also claims electrical conductivity that may be best. However, I have no issues using Arctic Silver thermal grease, which claims to be electrically non-conductive. There is still enough metal to metal contact for electrical continuity. This will ensure the FSD has a short and large path to ground in case it does try to offload excess voltage through its chassis.

I also believe FSDs are sensitive to voltage problems in the vehicle. Jump starter chargers, 50+ amp ones, should not be used on a 6.5L EFI diesel. These are somewhat unregulated and may spit out 18+ VDC which can harm many electronic devices. The PCM has power conditioning circuits, and all the sensors are buffered by the PCM's reference voltage, but the FSD is not. The FSD gets straight ignition voltage for primary power. Same goes for the Glow Plug (GP) Controller and GPs, which can be damaged from over voltage. Shocking a component often does not lead to immediate failure; it can begin the degradation, which worsens with use. This is why you might find you have FSD failures and GP system issues months after a stint of alternator or battery problems. If batteries are low, slow charge them if possible, or if in a hurry/stranded jump the truck with a normally idling vehicle. You can even leave a slow charger (up to 6 amps) on while cranking for a little help if no other vehicle is available. You might end up with less starting issues if you run larger gauge battery and starter cables, as it increases cranking RPMs considerably to significantly improve starting. FSD output can be tested using a digital volt/multi-meter, to diagnose no-start or surging idle condition; some diagnostics are at the end of this list.

(3) Oil Pressure Switch/Sender (OPS) relay modification, to take the load of the Lift Pump (LP) off of the OPS, because it burns the contacts within the OPS and causes the LP to stop working during engine operation. On the next page I provide a wiring diagram to add a relay, and also add fuel priming during the GP / Wait to Start (WTS) time, like OBD2 trucks have for easier starting. Something that improves access to the OPS, and simplifies wire routing is an OPS extension hose. PMDcable.com sells a nice 6" extension. The extension is essentially a 1/4" grease/hydraulic hose with 1/4" male and female pipe thread fittings. Additionally the OPS requires its threads to be grounded for the oil pressure gauge sender portion to work, which the crimped on fittings do by intentionally tapping into the hose's internal steel braiding.

Keeping the LP power tied to OPS output is to ensure the LP does not continue pumping in case of an accident when the fuel line at the engine could be severed. The engine dies and the LP would stop pumping because the OPS would lose oil pressure. If you tie LP power to the ignition, you must consider it will always be running when the ignition is in the On/Run position. Also, if you want the LP to run with the ignition, you should still use a relay, so the current for the LP does not pass through the ignition switch. For monitoring voltage to the LP with the engine running, you can probe the under-dash OBD1 diagnostic connector. In 94 contact "G" has LP power, contact "F" in 95. Applying voltage to these contacts, which go to the LP relay's normally closed contact, will power the LP.

(4) Change exhaust crossover to mandrel bent pipe and the turbo downpipe to 3" mandrel bent pipe (the downpipe will usually come with 4" exhaust kits, such as Diamond Eye). The stock crossover pipe is dual layered and often times the inside layer crushes internally while the outside looks fine. You can identify the stock crossover by its crinkle bends, which look pleated. The stock downpipe is a discontorted crunched up mess. The 4" exhaust systems do not typically include the crossover pipe.


94-95 OBD1 trucks Lift Pump (LP) prime during Wait To Start (WTS) and Oil Pressure Switch (OPS) relay modification: dual relays with single coil inputs by buddy
BATTERY
Fuseable Link
This power splice can come from any battery power source, such as junction posts on the firewall
TAN to I/P
A C D
OPS
Coil supression circuits are not required for this to work, but shown as an option for those that would like it
86
6A50V
30
87 a
87
RELAY 1
220Ω1W
85
Protection diode if not pre-existent within relay
Protection circuits not required
Supression resistor and diode values are approximate
RELAY 2
Cut this Grey OPS output wire to put it to relay contact 85 and other end goes to LP
The center normally closed contact 87a of relay 2 can be used for a LP diagnositic power switch, just run power to a switch, momentary or other, in the cab or engine bay, other side of switch to relay contact 87a to power LP for air purge, water draining, LP testing, ect...
Glow plug controller power output terminal
Grey wire from LP relay normally open (NO) contact
LP Fuse
Lift Pump (LP)

(5) Boost gauge (20-30psi max range), Exhaust Gas Temperature (EGT) gauge (1300-1600F max range) and a transmission fluid temp gauge (around 260F range) are always recommended. The next most useful gauge may be fuel pressure (15psi max range) at the inlet of the IP. That is to easily diagnose power problems, fishbiting, stalls, and prevent IP damage when it pulls a vacuum to suck fuel from the fuel tank. Tranny temp gauge not as important with manual tranny. The gauge ranges are not max operating parameters. Transmission oil should be kept to around 220F. You should not go over 1300F EGT pre-turbo (and not sustain more than 1000F for very long). Normal drivers should not push more than 15psi of boost, for serious risk of blowing head gaskets or worse. However with the right turbo, exhaust, head studs and PCM tuning, 20-25psi boost can help make a lot of power.

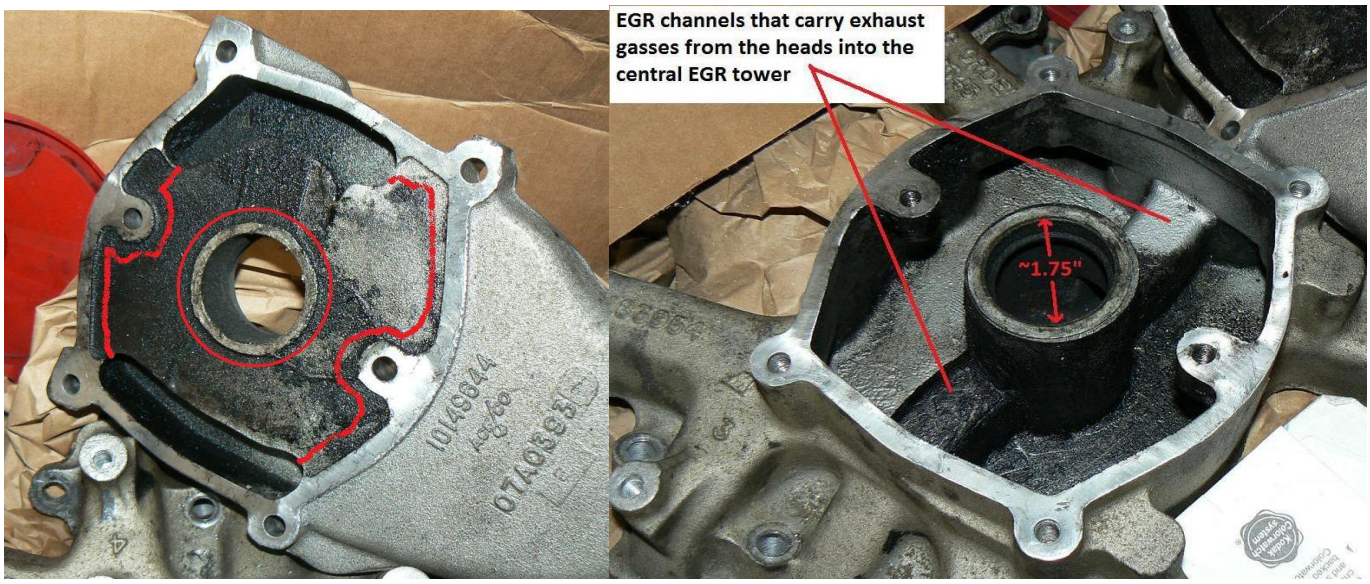
(6) PCM programming upgrades like economy or super stock, that provide improved efficiency, throttle response and overall driver satisfaction. This could be because you're not adding performance modifications, or the truck is for someone you don't want hot-rodding, or won't be towing. In 94 and 95 the brains of the PCM was located on removable Programmable Read-Only Memory (PROM). So an upgrade is a simple PROM swap that does not require a timing or anti-theft learn procedure.

(7) Upgrade the exhaust system to 4" from the turbo down pipe back (this is helpful at any earlier point); a muffler is recommended. There is a difference between a straight 3" system all the way back and upgrading to 4" from the downpipe back, stock is a mere 2.75". Fluid dynamics does not follow a weakest link in the chain theory. The longer the smallest diameter pipe is, the more backpressure it will create. Pipe alone causes backpressure, defined by cross sectional area and length. Turbochargers work off of pressure differential, so the less backpressure on the exhaust pipe, the less drive pressure needed to make the same boost. That is more efficiency and power from less parasitic backpressure on the engine's exhaust stroke. It also means faster spooling and higher peak boost pressures, which is not as necessary on a GM turbo as larger ones, but also lowers intake air temperature (IAT) and EGT.

(8) Update the air filter box to the K47 cylinder air filter box in 1997+ 6.5 trucks with an Amsoil Nanofiber EaA111 air filter (theoilgeek.com knows 6.5s). Use a 3" PVC elbow (one male, one female end) to connect to factory rubber elbow. This can improve efficiency and power while lowering IATs and EGTs. The Amsoil filter is a dry element that can be vacuumed clean for 100,000 miles, flows like a K&N without oil or wet cleaning/drying, and it filters air like an OEM paper filter. If still there, remove the plastic snorkel piece inside the fender; so the turbo can pull from the entire fender volume. No high flow flat panel filter will be adequate, as the cylinder filter has 3 to 4 times more surface area. The thick plastic of the K47 air cleaner box offers durability, stock appearance, and insulation from engine bay heat. It can be sourced from salvage yards, local or online, such as Car-Part.com, or a dealer may source them.

(9) Make sure your intake is free to flow. Those with EGR setups, but not concerned with inspection requirements, can change out their lower and upper intake for one with no restrictive EGR plumbing. Also many of the early year non-EGR "F" engines had the restriction plates in the upper plenum, without the extra channels inside the lower manifold. The upper plenum you can simply cut out the extra restricting material, and if it is an EGR upper plenum make and bolt down a block off plate. If not actually changing out the lower intake manifold from an EGR setup it would be best to plug the center exhaust gas tower with an appropriate sized freeze plug a bit larger than the approximately 1.75" (45 mm) diameter hole. The exhaust gases travel through ports in the heads, a channel inside the lower intake and up this central tower to the upper plenum where the EGR valve resides on top. The ports in the heads can be blocked with a non-EGR gasket, otherwise the tower should be plugged so exhaust cannot leak between the lower and upper intakes. There is and should have been a gasket for the EGR tower between the upper and lower intakes, but it can leak and better to just plug the tower in the lower intake. After blocking ports at the heads or plugging the tower the EGR valve could be left in place for a stock look. Most people request that EGR DTCs be disabled even if the system is left in place.

The below pictures show the upper “S” intake, with the extra restrictive plates outlined to cut. Some non-EGR “F” intakes also had this restriction in them, but with no holes for the EGR valve. So even if it is an “F” intake it would be best to check. The lower “S” intake is pictured to the right.



(10) Upgrade the LP to one that can provide 12-14psi fuel pressure at 50gph or better, such as the Delphi FP953 Cummins replacement, FASS, or Airdog LPs, each of which requires different custom installations any amateur plumber could manage with the right fittings. PMDcable.com actually sells a convenient Walbro FRC10 capable of 16psi at 50gph, includes the OEM electrical connector, has voltage protection, is flow on fail and safe for all fuel types. This upgrade is of importance when getting PCM programs with greater fuel output. GM technical data shows the IP should have 6-9psi at its inlet for proper operation, but even stock on many trucks its only 5psi at idle and can fall to vacuum under load. That is because they used a 9psi LP but put a 5 micron filter and restrictive Fuel Filter Manager (FFM) housing between it and the IP, which will drop fuel pressure ~30%. Under load with a power PCM PROM you can drop a healthy system down to 1psi pressure, and you lose power.

It is also possible to use two LPs in series, such as two OEM LPs plumbed in series. The OEM type LPs have a high failure rate within 1 year, which is why fuel pressure gauges are important. The Walbro FRB5 is a good LP for better reliability and better pressure than the OEM type LPs, but even it can be taxed by my high performance programming, so that it could even be assisted by keeping the OEM LP in series with it. If purchasing OEM LPs, select the unit for 1993 6.5TDs, as it is usually cheaper, but made to a higher pressure spec and installs identically as stock.

(11) PCM programming upgrades for towing, high performance and racing. This is where being able to get a staged chip for your truck can be convenient. You can order all of the performance options with safe detuned options at the same time and use them when the truck is ready, or even give them a try to find out what kind of performance gains await you.

(12) Cooling upgrades for towing, which are beneficial for reliability at any point. It is important to also understand that cooling upgrades could result in loss of some efficiency. Hotter engines can run more efficient, and cooling systems take power to remove heat. But when properly set up, with the right thermostats and the fan clutch engaging correctly you'll do great. Until 1997 a 90GPH water pump with unintentional unbalanced flow between heads was utilized with an inefficient 6-blade steel fan. Fan clutches also lose engagement ability along with not engaging early enough. I highly recommend the

2000 year 130GPH OEM water pump with spin on fan clutch, as it has the best flow balance to prevent #8 cylinder scuffing and scratching. When upgrading to this water pump you will need a spin on fan clutch. The OEM spin on fan clutch is acceptable with the 2000 year OEM 20" 9-blade steel fan, however the bimetal coil on the front of the clutch would need modification to engage near 210F engine coolant temperature. Getting over 220F coolant temperature can cause engine damage. To modify engagement remove the coil held in by a glob of adhesive or silicone and shorten the bent tab that holds it in place. Shorten it by flattening it out and bending it about 1/8" closer to the end of the coil and securing back in place with some silicone. Then test the engagement temperature under heavy load. The fan is easily felt and heard when it engages, and you do not want it before 210F for efficiency purposes. However, since you are upgrading, if this is a tow vehicle this is a good opportunity to upgrade to an HD clutch with a plastic Duramax 21" fan.

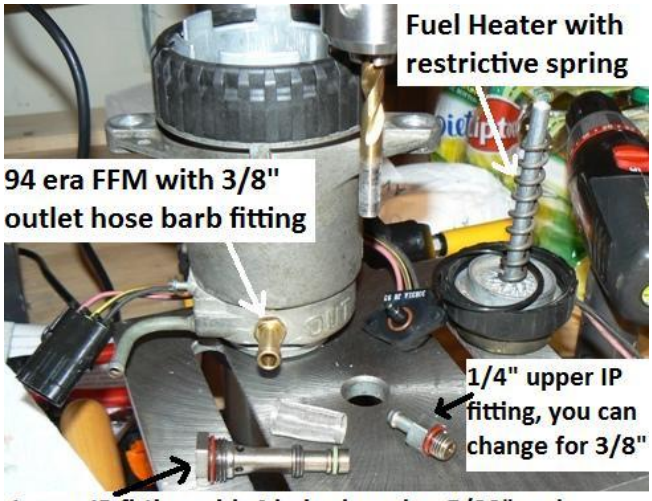
The Duramax fan also fits to the OEM threaded clutch, is lighter, and pulls more air than the 9-blade steel fan. It pulls more air even at idle in free spin keeping engine bay temperature low at all times. HD clutches have a higher engagement; standard clutches may engage 60-70%, where HD clutches can get 80-90% of full engine speed and last longer. I recommend keeping the single thermostat housing, because it pushes all water to the radiator and doesn't bypass some warm water back into the heads like the dual thermostat housing. The single thermostat housing also gives you easier access to the IP area, making the timing procedure very simple. I also recommend always using an AC Delco 195 degree thermostat (12T45E for single t-stat) for best engine efficiency. Using a lower temperature thermostat could cause a loss of 1-4mpg. If you normally cruise at more than 195 degrees then the radiator likely needs to be cleaned by removing the radiator, which should be done as periodic maintenance if towing a lot, or putting a lot of miles on the truck. A radiator shop can hot tank them for best results inside and out. Or use a few applications of scrubbing bubbles and hot water with medium pressure (garden hose) on the outside and to flush the inside; high pressure sprayers could damage aluminum fins and cores. Cap the tranny oil ports when cleaning the radiator, but if also flushing it, don't forget to add fluid later.

When filling the system back up with water, consider using less than 50% anti-freeze concentration. Anti-freeze lowers the cooling efficiency of water significantly. If you do not live in cold climates, or towing your big summer camper, consider using only 10-20% anti-freeze and a bottle of Red Line Water Wetter or similar product. The Water Wetter replaces the lubricants and corrosion inhibiters that anti-freeze would provide, and increases water's surface tension to prevent localized boiling.

(13) Upgrade Glow Plugs to Bosch Duraterms, Part Number: 80034, these are self regulating and quick heating GPs that have proven themselves to have the best performance and reliability in the 6.2 and 6.5 diesel engines. AC Delco 60G GPs are also self regulating and reliable, just take longer to heat to full temperature. The PCM programming can increase GP time, and I do by default for easier starting, so either plug is acceptable if you already have working AC 60Gs. To check your GPs, disconnect the spade terminal and with a digital multi-meter check the ohms between the spade on the glow plug to its threaded body screwed into the head. There should not be more than 1 ohm resistance through a cold glow plug, but make sure there is some, like 0.5 ohms, because an open circuit, or "overload" on a multi-meter means it has completely failed. Poor GP performance could also result from a failing glow controller, so when changing the plugs, consider changing the controller as well.

(14) Upgrade the fuel line from the FFM to the IP. There is a 1/4" fuel line and fittings to supply the high pressure fuel injection IP, but 3/8" fuel line supplying the FFM. This modification is commonly referred to as "Feed the Beast" (FTB) and there are kits available online with fittings, hose and instructions if you do an online search for "6.5 feed the beast" or visit WalkingJdesigns.com. For those wanting to find their own fittings it is good to know that AN (Army Navy) fittings are standard sized, just divide the dash number by 16, i.e. -6AN/16 equals 3/8, so the inner diameter (ID) is 3/8". AN fittings have the same

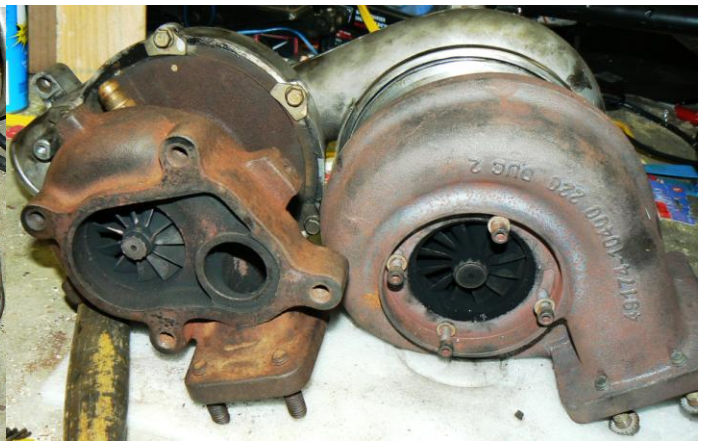
threading as JIC fittings, and at these low pressures they are interchangeable. The FTB 2.0 Stainless kit online is probably the best way to go for most people. When drilling out the FFM for 1/8" MPT to 3/8" fitting of choice, be careful not to hit the central fuel input shaft; I drilled the last edges with the bit backwards, or some may grind the bit tip flat. The lower to upper IP fitting is an uncommon 7/16-20 O-ring interface. A full flow steel upper fitting is rare, but can be purchased separately at WalkingJ. If routing the fuel line under the intake to the FFM, a full flow 120° to 150° 3/8" hose end should be used to attach the line to the IP. With a little hose and wire you can also relocate the FFM for easier access.



Lower IP fitting with 4 holes bored to 5/32" and screen that covers the holes. There is a screen on the bottom of the fitting too that should be cleaned.

For the serious performance seekers, the lower IP inlet fitting has four small holes (about 1/8" diameter) that can be bored out with a 5/32" bit, however this fitting is very very hard metal and difficult to drill, even with a drill press. I was able to bore them out but it took quite a bit of patience and a really hard, sharp drill bit and time on the press with oil cooling the bit and fitting. Also, in many stock FFMs there is a corkscrew, spring-like piece inside the central shaft that the fuel heater sticks up through which causes additional restriction. This corkscrew piece will slide right out and is unnecessary and not in later model trucks. While you have the FFM apart, consider changing all of the O-rings. You will notice that some FFMs have the drain fitting as pictured to the left, but others point straight out like the IP output, make sure not to mix them up.

(15) Upgrade the turbocharger to a larger one, such as an "A-Team Turbo" (ATT) kit for the 6.5 diesel ready to install, or HX40WII turbo chargers for "Super Drag Diesel" which would require some minor custom fabrication. Several other Holset turbos have been fit on there. This upgrade really works great, take the GM turbo heat shield off and look at how small the turbine housing is. Check out the pictures below, showing the small GM8 next to the ATT. The ATT turbine and compressor housings, and wheel diameters are considerably larger for better flow. The ATT turbine housing has no wastegate, and is technically a T4 mount, but it was tapped and studs installed in the T3 pattern for direct a bolt-on. The GM8 is a power/efficiency robbing restriction when increasing fuel output. The small turbo causes more parasitic engine backpressure than larger more efficient turbos that also reduce IAT and EGT, and sustain the power band to 4000rpm. If you do not maintain an EGR system the vacuum pump can be removed and a shorter serpentine belt used (aprox 101" belt). Although I recommend the vacuum controller for the GM turbo, if you use a mechanical wastegate actuator then you may also remove your vacuum pump.



(16) Water Mist/Methanol Injection (WMI) for towing or racing to help reduce IATs and EGTs. No more than 20% methanol mixture should be used in a 6.5 diesel, more could result in damage, because these diesels are not meant to have fuel until close to TDC of the compression stroke which can produce temperature of 2000F even prior to combustion, but the methanol will be sucked in during the intake stroke. Relatively small nozzles, such as 300cc/min and high pressure (100psi) are recommended for best atomization, use multiple small nozzles if more water is needed, and only high quality nozzles that have pop pressures that wont drip under 40psi or thereabouts. 100-120psi water pump recommended, or higher but regulated to 120psi max so you don't have push lock leaks or bursting lines. Using small electric car fuel injectors is possible.

Only inject water post turbo and with boost, 4psi minimum for full volume, or use a progressive controller based on boost starting at 2psi, or just one real small nozzle (150-200cc/min) at 2psi. A lot of windshield wash fluid is 99% methyl alcohol and readily available, just check the bottle, mix with at least 4 gallons of water. Some extremely small nozzles to make very fine mist can be used pre-turbo, but post-turbo will ensure no compressor blade damage. I recommend WMI over an intercooler, although intercoolers can be very helpful for hard working engines. Diesel combustion can be more efficient and smoother with warm air if not under load, like a daily driver. WMI only cools the air when necessary, provides additional catalyst/fuel, has cleansing affects, and increases compression while absorbing heat in phase exchange. After intake, exhaust and turbo upgrades the intercooler becomes less necessary.

(17) Fuel, oils, and their filters; keep your change intervals appropriate for the oil and filtering being used. I do not recommend anything other than diesel fuel used with the electronic DS4 IP. As previously mentioned, B5 fuel is a good choice for lubricity, but I do not recommend any higher concentration of biodiesel. That doesn't mean it won't work fine with B20 or higher. Anything that could impact the transparency of the fuel can negatively impact the injection system, because the OS must see through the fuel. When switching to a biodiesel blend make sure to check/replace your fuel filter after the first couple fill-ups. Before opening up the FFM, always drain about 8oz of water, sediment and fuel out the drain hose connected to the t-valve on the t-stat housing crossover. Draining should be done every so often as well, at least every couple months. Normal change intervals for this filter would be every 6 months or 8000 miles, but a post-FFM fuel pressure gauge could be your determining factor for filter changes. If you have not added a priming switch for the LP, the 94 models can simply press the slit on top of the LP fuse (on passenger firewall) up to one of the battery junction posts next to it. In 1995 trucks, you could put the transmission in gear and turn the ignition to Start/Crank and it will run the LP, but it won't crank with the tranny in gear.

There are OEM type fuel filters that have metal tops and use a separate plastic filter nut to hold them down. I use OEM type Wix #33376. Then there are larger fuel filters that the whole top is plastic and incorporates the filter nut. Some people have had trouble getting a good seal with the larger filter types, which can lead to fuel leaks or air intrusion. With the OEM type it is imperative that you line up the notches by correctly clocking the filter to the FFM. It only sets down one way for proper seating. Also make sure old filter gaskets are not left on the FFM before installing the new filter. While the filter is out, check the "last ditch screen" fuel strainer (Stanadyne #29244) that slides down around the central FFM shaft and commonly gets pulled out and discarded with the filter. The last ditch screen can also get clogged with sediment and gunk, just as the "tank sock" on the fuel sending unit (FSU) in the fuel tank can. Either being clogged can result in low fuel pressure at the IP inlet and poor performance. However, a clogged tank sock would also show low fuel pressure at the water/fuel drain, whereas a clogged last ditch screen would actually help to create good pressure at the drain hose. That is because the drain hose is pre-filter, and a restriction after it will help build pressure, yet another reason to monitor fuel pressure at the IP inlet.

If dropping the fuel tank, consider removing the tank sock and instead putting in an external filter before the LP, a simple large strainer, or a 30 micron filter/water separator setup. With the added filtration the interval on the stock filter can be increased. Fuel heaters help maintain a low diesel fuel viscosity for optimal atomization when injecting it into the cylinder. A scanner will show fuel temp in the IP, and if it is under 110F after driving a while then the stock heater likely isn't working. The FFM heater is supposed to run with ignition power, so you can test that with the filter out, if the central shaft of the FFM gets warm. Vegetable oil, while really not recommended, absolutely has to be over 150F before using it in the injection system, and never left in the system at shutdown, or mixed more than 5% with diesel fuel.

If you are using the stock oil filter and regular 15W-40 oil I recommend changing the oil every 4000 miles, or every six months, whichever comes first. Synthetic oils can double those intervals, but in either case make sure to check your oil level occasionally. If you're adding new oil frequently I suppose you could extend the complete oil change interval, and you should ensure the crankcase depression regulator (CDR) is not stuck open. The CDR (NAPA # CRB 29445) is the large tuna can looking thing on the passenger valve cover connected to the air intake elbow, it is a positive crankcase ventilation (PCV) valve for diesels. It is supposed to limit vacuum from the turbocharger, so oil does not get sucked out. You would be better off venting the valve cover to the atmosphere (like an old breather, or road "draft tube") than operating the engine with a non-functional CDR. Engine blowby can make up nearly half the emissions from a vehicle, which is why the PCV valve was implemented, to burn those fumes. Having a slight vacuum in the crankcase also helps prevent oil seals from leaking. Older 6.2L diesels and the latest 6.5L diesels pull a vacuum from the oil fill tube, where there is less likelihood to suck oil out. The oil fill tube from those engines could be put on your engine. There are also ways to modify the CDR to have it regulate at lower levels of vacuum (as it is supposed to) to reduce oil consumption; just do an online search for "CDR experiment".

For 2WD trucks with vertical oil filters you can use a 2 quart oil filter for added oil capacity and filtering. I use the Wix #51794, available from the Amsoil oil geek as well, but it has no anti-drainback, so it must be used vertically. 4WD trucks use a horizontal filter adapter that can be changed to a remote adaptor, to add filtration, capacity and cooling. The additional capacity itself provides added cooling benefit. More filtration and capacity, combined with synthetic oils can increase change intervals to 10,000 miles, or once per year, whichever comes first. Synthetic oils can be used in even longer intervals, but oil analysis is recommended to verify its condition. In cold climates I recommend synthetic 5W-40 diesel oil, Mobil1 TDT or Shell T6, for easier starting and smoother warm-up. I am now using Shell T5 synthetic blend 10W-30 diesel oil. Synthetics provide superior performance at high and low temperatures, and easier flow for potential efficiency gains, using lighter weights. Amsoil even makes a full synthetic 5W-30 for pre-2007 diesel engines. Lighter oil weights may also increase oil vapors and observed blowby, with increased oil consumption, so its important to check the oil level occasionally. Amsoil has heavier synthetics with superior vapor resistance that could reduce visible blowby.

Adding oil capacity and oil cooling for hard working engines is a good way to remove heat from the heads, cylinders and turbo. In some cases this can be more effective than water cooling upgrades. The same goes for adding capacity to your transmission and gear differential, using larger, deeper covers that also shed heat better. If installing a deeper transmission pan and new filter, it might be a good idea to change all of the electric solenoids in the tranny (whole kit $140 at electricaladvantage.net) and perform the Sonnax Sure Cure kit update ($86), which can make it more reliable with a new firm feel. This addresses the 4L80E's most common wear items that can make an otherwise great 300,000 mile transmission seem like junk. Synthetic oils can also perform better in hard working transmissions and gear differentials.

(18) Head related maintenance….ARP Head Studs are a must, never use the crummy torque-to-yield (TTY) bolts on this engine again. Lowering compression ratio (CR); I recommend dropping the CR to

approximately 20:1. This would be accomplished by using a +0.01" thickness gasket, or -0.01" compression height pistons. If decking the block, you must also take that loss of height into consideration. A combination of methods, or a custom +0.02" or thicker gasket from Cometic could be used. The standard thickness head gasket is approximately 0.045" thick. On the topic of heads still, I will also point out that you can gain considerable responsiveness using the latest style pre-cups from later year models. The diamond etched pre-combustion chamber cups have larger openings to support more power from higher fuel rates. The 94 and 95 engines had smaller mouths and smaller inner volumes as well. GM dropped the CR in later models by using pre-cups with more internal volume. The diamond pre-cups have slightly thinner walls and larger opening which means more volume to lower the CR. The differences can be seen below. The larger mouths can put more combustion expansion pressure onto the piston during peak torque angles up to around 76° after TDC.

The diamond pre-cups should come in new heads, or you may be able to source a set from engine builders to install in your heads. There are genuine GM/AMG pre-cups, then there are also aftermarket ones. The aftermarket foreign pre-cups are made from presumably inferior metals, as they are magnetic, whereas the genuine ones are not. The two also have internal cup porting differences as seen to the left, two different diamond stamped pre-cups. The center cup with distinct machine lines is genuine.

(19) The harmonic balancer (HB) is key to keeping your bottom end from breaking at any power level. There is the primary HB and then the secondary HB which doubles as the crank pulley. Cracked and broken rubber can lead to broken crankshafts and presumably more main web block cracks. Inspect these items, and if replacing, consider the Fluidampr HB. If not for ensuring your new found power doesn't leave you with a two piece crank, then do it for a smoother, more comfortable and "civilized" ride. The Cadillac of diesel trucks, especially with the super comfortable captain's chairs in the 1994 models. The Fluidampr HB replaces only the primary HB and it costs about 3 times more than a standard replacement. It is a peace of mind, creature comfort upgrade, but an actual noticeable upgrade in vibration dampening.

(20) Injectors are standard 100,000 mile maintenance items; in high power, heavily loaded trucks I recommend rebuilding at 50,000 mile intervals. I have seen burnt nozzles dribble fuel in much less mileage. These injectors are purely mechanical; they pop at a set pressure generated by the plungers in the IP. Stock pop pressure for non-turbo engines is 1850psi, turbo injectors are 2100psi and marine injectors are 2200psi. The non-turbo and turbo injectors use the same nozzle (SD304), but the marine nozzle orifice is slightly larger (SD311). They all use identical injector bodies, so the nozzles and injectors are interchangeable. Injector health is very important for a well running, reliable and efficient engine. Poor performing injectors can go undetected very easily. Low pop can make the engine run smooth at idle and low load, but not spray well for efficient combustion. That can lead to high EGT and poor MPG under load. Injectors can leak overnight, because there is always pressure in the lines, about 125psi after shutdown. Fuel in the cylinders will wash away lubrication and cause scuffing and scratching on subsequent cold startups.

Several injector rebuilders are out there, but I prefer to have mine rebuilt with known nozzles and set to specific pop specs. A diesel injection shop should be able to change your nozzles and set the pop pressure for about $120, perhaps they'll let you watch. I use marine nozzles, but standard nozzles are adequate for most trucks, and those wanting best MPG. The only nozzles I like using are German Bosch, but Bosch

also produces them in India, and there are knockoffs too, so you may have to search a bit to find the German ones. I have my marine injector pop pressure set to 2350psi, and recommend standard injectors set to 2250psi for performance applications. Pop pressures will settle about 100psi lower after a several weeks. Each injector should be set as close to each other as possible, with a maximum range of 50 psi. Production tolerance on eight new injectors could be as high as a 400psi range.

Consider that cylinder air pressures approach 2000psi during injection, if running 15psi of boost with a standard CR of 21.3:1. When running higher fuel rates and higher boost it is advantageous to have higher pop pressures for better atomization. Pop pressures on other types of diesels are much higher, but I would not set it over 2600psi pop pressure because the DS4 can only build so much pressure at cranking RPM, and starting cold could get difficult. The IP can generate around 4000psi at idle RPM. Other reasons to increase pop pressure would be modifications that significantly reduce compressed air temp and combustion efficiency, such as low CR. Many believe that marine injectors providing more power is a myth, however it is not. The marine nozzle has a larger orifice that can allow more fuel to be injected before the injection event stops with the opening of the IP's fuel solenoid metering valve. Injection volume is a combination of IP transfer pump pressure, which rises with RPM (30 to 125psi), and time (pulse width). With the same amount of time more fuel can flow out of a larger orifice. Marine injectors are most useful when higher fuel rates are commanded from reprogrammed PCMs.

When installing the injectors there are special sockets made to prevent breaking return nipples, such as Kent-Moore injector tool J-29873 or similar. Injector replacement kits come with copper crush washers that must be used. Do not reuse old copper washers, use anti-seize compound on threads, and torque injectors to 55ft-lbs. Make sure everything around the injectors is clean before removing them and handle new ones with care, as to not foul any during installation. New injectors with high pop pressures can increase engine noise, but quiet down after about 1000 miles.

(21) It's all about the flow, more head related modifications. Those after the most reliable and efficient performance possible have some further options, which if rebuilding or refreshing an engine may be a reasonable time to implement a few very helpful modifications. To minimize your engine's air pumping losses there are additional upgrades beyond the larger turbocharger. The least of which is extrude honing the cast exhaust manifolds, this process is costly ($750), but is highly beneficial. Then there is the airflow of the heads themselves, and with shipping and extrude honing prices it is impractical. However, you can get new cast, made in the USA, AMG pre-ported heads from Peninsular diesel. The real difference maker though, is that you can purchase or have Peninsular mount a set of adjustable roller rockers in the heads, and they come with performance push rods. The roller rockers are stronger and provide less friction, together with the performance push rods results in significantly less deflection. The rockers are also higher ratio, 1.6:1 vice the stock 1.5:1 stamped steel. Combine less deflection with higher ratio and you get extended valve duration and lift for making better and more efficient power through the entire rpm range, and extending power beyond 4000rpm. The pre-ported heads with roller rockers will set you back about $2500, but will pay for itself in additional MPG and new found power. Peninsular also offers the strongest new 6.5 blocks from AMG, cast in the USA, so could be the entire repower solution for a real workhorse.

No-Start Diagnostics

If the truck won't start, first and foremost are the SES and GP/WTS lights coming on? If SES is not on with the ignition and GP/WTS doesn't work then you likely popped the ECM fuse, or the ignition switch isn't sending power to the PCM. If other stuff like dash lights or the radio doesn't work I would suspect the switch. Otherwise, check grounds, the ones on the passenger side of the engine, back of the intake and head. Also make sure the battery cables are secure and clean on the batteries. If everything seems to be in good order make sure to check the FSOL fuse, because it powers the PMD and ESO/FSO solenoid. If all fuses and grounds are good, then verify you have fuel pressure to the IP. That involves LP diagnostics, or simply verifying that while cranking fuel is pumping to the IP. Loosen the fuel inlet hose clamp on the IP and crank. Fuel should leak while cranking, and if it is, then tighten the clamp again while powering the LP so any air is purged. Some LP tricks are previously covered in the recommendations above. In a rare case, the fuel return line could be plugged, and disconnecting the return hose on the IP and routing it to a bottle to collect fuel may allow the engine to start.

This assumes that your engine is cranking fast enough to start. Batteries should be matched, if either one or the starter is bad it might not crank fast enough. Batteries need to be load tested and not just stabbed with a meter to see they are over 12V with no load. Either use a load tester with each battery isolated, or monitor voltage at the battery with a meter while cranking. If it drops below 10V then one or both of the batteries are bad, or check the water/electrolyte level in the batteries, fill with distilled water if necessary. They should be replaced as a pair if one is bad. This also assumes the engine is warm enough to start or the glow plugs are working. Check the glow system out, or plug in the block heater for a few hours to see if it will start that way.

If all seems well so far, then you can try unplugging the OS on top of the IP. The truck only needs one timing source to start and run, either from the OS or the CPS, and they check each other for failure. With either not functioning properly you would likely experience extended cranking times for starting. If it won't start after unplugging the OS, plug it back in and try unplugging the CPS. When one of these two fails or is unplugged it should set a DTC. If it is not setting the DTC then it can reveal an issue. Air in the fuel can often emerge as random OS or CPS codes, or simply mess with injection capability when starting. If the LP is working and you have pressure at the IP, then air could still be entering between the fuel tank and the LP, where the LP pulls a vacuum. No leaks would necessarily be observed, but an inspection for rusted and rotted fuel lines above the fuel tank could reveal the issue. This could also show up as fish-biting while driving until it worsens to causing backup fuel mode or not starting.

Hopefully you have a spare PMD, since it is often a cause of a no-start condition. Swapping PMDs is usually one of the first things I would try. Otherwise, if using an extension cable, try eliminating it to see if the situation improves. If that does not work, check the ESO/FSO solenoid. It should click when the ignition is turned on, because it lifts a plunger to allow fuel flow. If concerned about the ESO solenoid condition you can simply remove the plunger. Unplug the solenoid and twist it off the IP, and pay attention not to lose the spring under it. The plunger is held in by a snap ring, so find a snap ring pliers,

small to medium sized. The plunger will fall right out, and you can reinstall the solenoid body. Otherwise you could also just cut the plunger head off with a bolt cutter. The ESO solenoid is not necessary in normal EFI operation because the PCM and the PMD must have ignition power to even get power to the IP's electronic FS. The ESO solenoid is essential in mechanical fuel injection systems.

Below is a table of signals you can test at the PMD engine harness. You can verify the PMD is getting power, and that the PCM is sending injection signals to the PMD. Voltage measurements are approximate, give or take like 10%. I got the numbers out of the GM manual and/or verified on my engine with a digital multi-meter and an oscilloscope. Take notice that the PMD outputs a modulated pulse signal to the fuel solenoid (IP) that can be seen as alternating current (VAC). The digital multi-meter will display very close to actual voltage as seen on the oscilloscope, because VAC is an RMS value, and they have issues calculating the RMS of a square wave, and tend to just show the peak to peak voltage. In this case the voltage goes from 0 to 1.2VAC, 1.6VAC, ect… The PMD output will increase in voltage with RPMs. If during crank you have a value 50% higher or greater, it could be that the power or ground to the IP has been broken, there should be 0.4 ohms between PMD harness sockets B and F.

Signal	Ckt/ wire color	PMD pin	F/Sol harness	IGN on ENG off	ENG idling	ENG crank	OBD1 PCM pin
fuel inject control	984 Lt Grn	A	A	GND	1.9VDC	≥1.2VDC	BC14/BD13
fuel inject signal	985 Red	E	D	5.6VDC	4.0VDC		PC2
IGN pwr F/Sol fuse	339 Pink	D	C	B+	B+	B+	-
PCM closure GND	950 Lt Grn	C	B	GND	GND	GND	PD2
F/ Sol Signal	Red	B	-	0	1.65VAC	≥1.2VAC	-
GND thru F/Sol	Black	F	-	GND	GND	GND	-

B+ = battery voltage, approximately 12V with ENG off and 14V with ENG idling

PCM connectors/pins : 1st letter is color of the PCM connector, 2nd letter is row in that connector

BC/BD = 32pin Blue connector PC/PD = 24pin Pink connector PA/PB = 32pin Pink connector

PMD tests for surging or no-start……

If the engine is running look at the fuel rate and desired idle values using a scanner. If the PCM is commanding a steady fuel rate less than 10mm3 it should never go to 3000rpm, which you can also see by the desired idle value. If rpm is constantly going up and down, you probably have a broken IP. The PMD output can be tested by using the following method. You will need to access the red wire in position "B" of the PMD connector with the PMD plugged in. This can be challenging with the intake manifold installed if using an IP mounted PMD. Straighten out a small paper clip and push one of the pieces of paper clip into the BACK of the PMD connector right alongside the wire to pin B. Push the

piece of paper clip gently between the rubber seal and the wire. Wiggle the paper clip and push gently until about an inch of the paper clip is no longer visible. The paper clip should now be touching the back of the bare metal terminal connected to the wire. Use your ohm-meter to ensure that the paper clip is indeed making contact with the respective socket in the connector. If you have wire piercing probes they can also be used, or you can strip a small section of wire to clip a meter lead onto. Remember to repair the wire insulation later though. Now, plug the PMD connection back in. Connect your volt-meter lead to the pin B wire and the other lead to the ground on top of the IP, with the meter to measure AC volts. Do not to let the paper clip short against engine ground or risk PMD damage.

Crank/Run the engine and observe the voltage. You should observe at least 1.0 VAC while cranking, up to 1.4VAC. If the engine will not start and this value is lower, then the PMD is likely bad. If the engine will not start and your voltage value is higher than 1.4VAC then the connections to the IP's Fuel Solenoid (FS) under the rubber boot probably have broken loose. You can ensure the connections are good by measuring the resistance from PMD pin B to pin F, which should read approximately 0.4ohms on a healthy FS. While idling you should observe approximately 1.6VAC. The voltage will rise with RPMs, up to 5VAC around 3500rpm. If your PMD is outputting between 1.0 and 1.4 VAC and there is no fuel at the injectors, then the IP is likely faulty. If your PMD is outputting a constant 1.6VAC or less at idle, but the engine is revving uncontrollably then the IP is faulty. None of these tests prove that a PMD will not later cause stalling, but it should start and operate the engine.