Turbo Diesel Buyer's Guide

A Publication of the ***Turbo Diesel Register***

SO YOU WANT FUEL ECONOMY

IT'S ABOUT THE (fuel) ECONOMY STUPID!

by Robert Patton

No, I'm not running for office this election year. But, with my knack for the obvious, I know the focus of attention is fuel economy. So much so that I could be accused of head-in-the-sand mentality were I not to acknowledge that I've heard many conversations about parking the truck and purchasing a beat-up economy car.

I've thought the same. Before you make a like decision, be sure to factor *all* of the cost. You'll likely find that the beater car's payback is longer than you first realize.

Nonetheless, I wanted a quick solution to the fuel economy crisis. So, I went to Wal-Mart.

No magic fuel magnets were found on the shelf. Out of stock.

The air tornado thing was not large enough for my truck's intake.

The fevered pace with which I started this article was now in neutral. If the fuel magnet or the tornado salesman had come calling I would have purchased the products out of sheer frustration. Maybe I should do some further research.

As I look back, it was 10 issues ago (Issue 51) or the winter season of 2005/2006 that we had the TDR writers tell us about their strategies for driving their diesel in a $3 gallon world. This was just after hurricane Katrina, but prior to ULSD fuel and the higher world wide demand for diesel. Diesel fuel was still lower or equal to the price of regular grade unleaded gasoline. Diesel owners were still pleased with their choice of engine and we enjoyed the benefit of the engine's 35% better fuel economy than the gasoline counterpart. Today's price premium for diesel fuel (about 20% here in Georgia) really hurts.

So, I went back to Issue 51 to see how easy it might be to write a sequel article. I was captivated by the writer's stories.

Issue 51, like a conversation with an old friend, is worth your reread.

- Doug Leno's cost/benefit analysis on fuel economy gadgets.
- Brad Nelson's pinecone and boost build-up driving technique.
- Bruce Armstrong's EGT at 600° driving technique.
- Greg Whale's analysis of price versus Europe where fuel was $6 for diesel and $8 for gasoline.
- Scott Dalgleish's fuel economy project truck and the connection of the wallet to the right foot.
- John Holmes' price of fuel versus minimum wage comparison.
- Jerry Neilsen's pledge to slow down and use the cruise control. Jerry also noted that "everything is a matter of perspective."
- Joe Donnelly points out the obvious and refers the readers back to Issue 47.
- Mixed in with the fuel economy comments you can't miss the late Ron Khol's tell-it-like-it-is political commentary.

Throughout Issue 51 several writers made reference to Joe Donnelly's "Fuel Economy with Power" article in Issue 47. So I picked it up and searched for information. Rather than reinvent the wheel (actually Issue 47's article was an update from Joe's Issue 29 material), I'll review with you some of the Issue 47 text.

The first thing that caught my attention was the cliché often seen in the TDR, "The more things change the more they remain the same." As this bit of reality set in, it slowed my fevered pace to find the key that would unlock a dramatic fuel economy breakthrough.

Regarding fuel mileage (and for that matter performance and exhaust emissions), this bit of reality was presented in Issue 47.

"Editor's note: you may say to yourself, 'Gee, it looks all too simple…change (advance) the timing of the fuel delivery (on the 12-valve engines this is a mechanical change; on the 24-valve engines and HPCR engines many of the auxiliary black-boxes do the timing change) and throw in a set of big injectors for better mileage and power. Pretty simple, eh? Why didn't those guys at the factory do that?' The answer is as simple as two words: exhaust emissions! Dodge and Cummins have to play by a different set of rules than the owner of the vehicle. It is true that tampering with or disabling any component of the emissions control system (timing changes and big injectors *are* included here) is a direct violation of federal law (fines up to $25,000 per day, per violation). Owners have to weigh the consequences versus the increase in performance, and in this example, fuel mileage (Issue 60, page 50)."

Some other summary points from the Issue 47 text:

The article provided a great refresher for 12-valve and 24-valve owners. Of particular interest to all of the TDR audience is the discussion on brake specific fuel consumption (BSFC) and volumetric efficiency (VE). We provided the performance curves for an early Dodge 12-valve, 175 hp engine. We also provided a preliminary performance curve for an early 24-valve (non-Dodge application) engine. Unfortunately the Dodge-specific curves for the '98.5-'02 engines were never published for the Cummins network, as the Dodge engine is not an engine sold through the Cummins distributor system.

The same story holds true for the '03-'08 Dodge-specific Cummins engines.

Regardless, we can all learn from the BSFC and VE discussion and benefit by driving close to the engine's BSFC and VE "sweet spot." For 12-valvers it's 1600-1700 rpm; for 24-valvers it's 1600-2000 rpm; for HPCR engines it is a higher 1900-2100 rpm range as confirmed in discussions with Cummins Inc. engineers.

From these performance curves I want you to focus on the bottom chart "Fuel Consumption." The measurement used is brake specific fuel consumption (BSFC). In layman's terms, brake specific fuel consumption is the efficiency of an engine. The BSFC number is simply a value that helps us desribe the engine's ability to convert fuel into horsepower.

BSFC tells you how much fuel it takes your engine to produce each horsepower. The lower the BSFC value, the greater the fuel efficiency: Fuel consumption (gallon/hr) = (BHP x BSFC) ÷ 7.1 lbs/gallon fuel.

Been There, Done That; Got Lots of Spare Parts

As much as I would like to pretend that I am a diesel engineer and offer you a magic fuel economy fix-all, the reality is that as a group we have already been there and done that. So much for the sensational title line that I could splash on the outside cover, "Writer Dude Discovers 25% Greater Fuel Economy for His Dodge/Cummins Turbo Diesel."

Back to the task at hand, can you increase the fuel economy of your truck? Oddly enough Issue 51 was the second article in Scott Dalgleish's quest to improve the mileage on his '05 Turbo Diesel 2500, 4x4, Quad Cab with the G56 six-speed transmission and 3.73 rear differential ratio.

Rather than send you back to your archives to gather the information, I've assembled a brief summary of each of his articles.

Read the summaries and let's see if we reach the same conclusion(s) at the end.

I 50 Baseline MPG 15.8 city; 9.8 towing.
Added TST PowerMax CR, Amsoil synthetic lubricants, Mag-Hytec differential cover, gauges, fresh air box with aFe Proguard 7 filter. Notes: Playing with different timing settings the TST PowerMax CR showed an increase of up to 13% better mileage.

I 51 Added Gear Vendors overdrive, Banks High Ram inlet, Banks intercooler, Banks Monster exhaust. The combined effect of the aftermarket products thus far: up to 17% better.

I 52 Added BFGoodrich 285/70/17 tires which reduced engine's rpm by 100. Experimented with pre-production Banks Six-Gun Tuner and Power PDA. The combined effect is still in the 16-17% range with the power setting on the Banks unit at "2."

This comment caught my eye: "Power settings above 2 provide marked performance increases along with an equal increase of driving fun. But the fun has a cost and decreased fuel economy is the price."

Scott is about to "go over to the dark side," "fall off the wagon"; choose your cliché. This article was written in the May 2006 time frame when the pre-Katrina fuel price is at a stable $2.25.

I 53 No report.

I 54 Recap of baseline at 15.8mpg. Noted increase of mileage to 18.7mpg. Added Industrial Injection Super Phat Shaft 62 turbocharger and PDR camshaft. Scott noted that the turbocharger neither hurt nor helped fuel economy.

I told you Scott had moved to the dark side. Notice the emphasis on performance: "The setting of the Banks Speed Loader was 6 and the 0-60mph time dropped from 10.2 seconds to 8.9 seconds.

In the Issue 54 article Scott noted that the PDR camshaft had a dramatic effect on economy—approximately 2.1 mpg. Great news! But, why didn't the Cummins engineers think of that?

They did.

Scott's explanation from Issue 54: "If obtaining better fuel economy can be found from a different cam grind, why didn't Cummins do it?" The answer is Cummins Inc. can provide camshaft grinds for better fuel economy. But, as I stated earlier, Cummins has to abide by a different set of standards, which are primarily emissions driven. ***(Editor's note: Sounds familiar, doesn't it?)*** In order to meet current NO_x standards, combustion cylinder pressures must be lowered. One way to accomplish this goal is to retard injection timing, reducing cylinder pressure and thereby reducing NO_x. The Catch 22 is that it takes more fuel to operate the engine in this manner. The engineer has to certify clean exhaust emissions, often at the cost of fuel economy. So will the cam offered by PDR meet EPA emission standards? To our knowledge it has not been tested for EPA compliance and probably would not pass. Would it pass a local emissions test as administered (snap idle)? Probably."

I 55 Scott is to the point: "In my review of some of the back issues I realized I have made a transgression. I have once again, fallen to the temptation of more power. While it is true we are close to accomplishing our goal of 20% better fuel economy across the board, the alluring power increases have blinded me like a moth drawn to a bright light. I now believe that it is possible to obtain the 20% fuel economy goal AND increase horsepower to the 500-rwhp mark. Along with this revised goal I had to accept the reality that was true for me way back in Issue 23, the financial impact of all of these fuel mileage and performance goodies will never be offset by the 20% economy I may someday achieve."

Further, Scott writes, "This isn't to say I have forsaken the fuel economy project. Currently we are averaging about 18.1 mpg. That is approximately a 15% increase across the board (solo, towing, city and highway). We have produced as much as 18.8 mpg driving solo combined city and highway, which is a 19% increase! But we have shifted from some of the original stated criteria. Most notably, 'to remain emission compliant and to maintain the factory warranty.' Some of the parts we have tried may not be emissions compliant (no current emissions testing data is available) and their effect on warranty is subject to debate.

"Knowing this up front, you are faced with a dilemma. Will you a) live with the fuel economy offered by the current HPCR engine's configuration; b) make some of the changes which provide some fuel economy improvement and leave the engine warranty intact, or c) become your own warranty station and move in the direction which will provide the best fuel economy and performance available?

"On the topic of emissions compliance: most, if not all, of the products tested to date will pass the current snap-idle emissions testing which is performed in some states today. Would these products pass the current Federal standards? Probably not. We do not have access to the test equipment nor is there a standard procedure for such testing after a product is sold to the end user. Since no testing of the Federal emissions standard (EPA or CARB) is currently in place (the exception being for manufacturers), it is a moot point."

TDR members, if you reference Issue 60, pages 50-52, you will likely conclude that parts testing for emissions certification for the '03-'07 HPCR engine is still a moot point.

I 56 Noted a decrease in mileage of 7% that was attributed to the required ULSD fuel (January '07). Added DDP injectors and mileage checks in at 18.9 mpg.

I 57 Added Leer truck cap, but noted no difference in economy.

I 58 Changed turbocharger to a Turbo Re-Source unit. Mileage is 19.1 using Scott's combination solo runs on the short and long track.

I 59 A higher performance set of DDP injectors (DDP90) and an emphasis on horsepower. Fuel economy went down 6%. Overall economy is better by 14%

I 60 No report.

I 61 See Scotts turbocharger write-up on page 92.

Conclusion(s)

Credit to Scott—in his adventure seeking fuel economy and performance, he took the time to address three important concerns: Why didn't the factory engineer for fuel economy? What happens to emissions compliance? What are the effects to the factory warranty?

As I looked back at his findings, there was one modification where I could see a cost justification and two nice-to-have modifications.

The item that can be cost justified: The use of a performance box that modifies the timing of the fuel injection event. Cost: $800. Number of gallons that you would need to save (@$4/gallon) to payback the $800 ($800 ÷ $4 = 200 gallons). From his Issue 50 Scott found that the mileage increased by 13% or 15.8 x 1.13 = 17.8 mpg.
Drive 30,000 miles ÷ 15.8 mpg = 1,898 gallons used
Drive 30,000 miles ÷ 17.8 mpg = 1,685 gallons used
213 gallons saved

Okay…drive the truck 30,000 miles and you've paid for the performance/timing box.

The nice-to-have modifications: The camshaft and the overdrive unit.

From Issue 54 Scott noted the cost of the cam and installation was $1600. He noted a 2 mpg increase. Yet the 2 mpg was lost (the numbers should have gone up to 19.8 mpg) in his quest for power. But, for the sake of argument, let's assume another 2 mpg improvement.

At $1600 ÷ $4 gallon you need to save 400 gallons of fuel to pay for the camshaft. This would take 60,000 miles.

And the nice-to-have overdrive? Writer Loren Bengston covered the payback for his overdrive unit back in Issue 47, page 162. In Scott's case insufficient data exist to do a calculation.

Bottom Line

It seems simple to me…

- As we learned from Joe Donnelly and Issue 47, operate the engine at the BSFC rpm that corresponds to the engine's sweet spot. Unfortunately, highway speeds don't allow you to go that slow without impeding traffic, so slow down as much as possible.
- Change the engine's timing. Scott's findings and the article by Joe Donnelly on page 98 confirm that this modification is applicable for all years of the Turbo Diesel truck. Be careful of the cause and effect and realize that the payback could take a while.
- All of the other modifications are discretionary.

Robert Patton
TDR Staff

P.S. Wal-Mart is *still* out of stock on the fuel magnets and the tornado thing *still* has not been released for our intake size.

VENDOR RESPONSE TO THE NEED FOR TEST DATA

by Robert Patton

Realizing that there was limited data to substantiate the timing cause-and-effect, I sent a letter to several vendors that were listed in Issue 47's and 48's articles on performance for the '03-'07 HPCR engine. The articles were authored by writer Doug Leno and Doug provided a comparison matrix that showed vendor products that effected timing.

Doug's write-up (Issue 47 and 48) was done in mid-2005. Since that time there have been numerous other products introduced to the market that effect timing. I was remiss in not asking those vendors to respond. Admittedly, I am belated in keeping tabs on the performance marketplace.

The following is the letter that was sent to those vendors of record in mid-2005 whose products effected timing and the responses that were received:

> *In Issue 61 the obvious topic for the TDR will be, "It's the (Fuel) Economy, Stupid!" We are planning a story on fuel economy and we would like to include your input in this article.*
>
> *I plan to poke fun at myself with an exaggerated story about out-of-stock fuel magnets and the Tornado-thingee that does not fit our diameter air intake.*
>
> *The serious stuff starts with this disclaimer: "Numerous times I have been cited for not including a legal disclaimer prior to an article that discusses a performance gadget, gizmo, or modification. Make no mistake: changing the timing of fuel delivery is a modification that can put your rights to warranty consideration into serious jeopardy. Additionally, timing changes must not adversely affect emissions according to the Clean Air Act, Section 203(a) and EPA Memorandum 1A."*
>
> *This disclaimer will be followed by Joe Donnelly's "How-To" material on fuel pump timing for better fuel economy. Joe covers the mechanical VE and P700 fuel pumps, taking us up to the advent of electronics.*
>
> *At this point it becomes subjective with comments from writers, "I think…"*
>
> *So, I will jump on the band wagon. I think timing (either mechanical advance or electrical) is the magic bullet for Dodge/Cummins owners to consider in their quest for cost-effective mile-per-gallon gains. Have I missed the mark?*
>
> *Thus, the purpose of this correspondence is to allow you and your company a forum to present any fuel economy data you may have on your VP44 and HPCR boxes. To keep the correspondence on track, I have provided a Question & Answer format below. I would appreciate your responses to these questions.*

I received a response from TST Products' Mark Chapple and MADS Electronics' (Smarty) Marco Castano. Their answers make up the balance of this article.

Is fuel injection timing a "magic bullet" or is the editor off-his rocker?

TST Products' response: I don't see it as a magic bullet, but I believe there is a definite trend. As emission laws get tougher, manufacturers retard timing to reduce NO_x. The reduced NO_x comes from lower cylinder pressures and temperatures, but this is the opposite condition one would want for best fuel efficiency.

MADS Electronics' (Smarty) response: I'm sorry to say, timing alone is not the "magic bullet."

Let me expand.

The mechanical VE and P-7100 injection pumps have a preset and fixed value for the "beginning of the injection stroke." This means that the preset timing is optimal only for a rather narrow RPM/load range of the engine.

Since the introduction of the first "real" emissions regulations (NO_x, HC and PM emissions) all engine manufacturers were forced to introduce electronic engine management. The introduction of electronic control modules provided a much more refined control over the injection timing. Electronic engine management provides the ability for dynamic timing changes throughout the RPM band. Therefore not only RPM, but parameters like engine temperature, boost pressure, intake air temperature, etc., can now be taken into account to adjust the timing of the engine.

Were there no such thing as emissions regulations the electronics could provide the "perfect" timing for the engine. Thus the best possible mileage?

Unfortunately, the world is not a perfect place…

In order to reduce the combustion temperature thus NO_x and PM emissions one simple way is to retard the timing. Furthermore, for the emissions test(s) the low load/low RPM range is weighted more than, let's say, wide open throttle. That means the high load/RPM range is less important from an emissions point of view.

This leads to what's under our eyes or should I say right foot? Detuned/sluggish engines in the 600-2000 RPM range. Range where we use them most! Detuned because of the emissions. Sigh!

This is of course counterproductive from the mileage point of view in a Diesel engine! As you surely know, the diesel engine is most fuel efficient in the lower RPM range; typically the best BSFC is yielded, which happens to be around peak torque.

Then faster the engine gets into the peak torque range then better its fuel efficiency in the real world. This is where the timing really comes into the picture! Correct timing means an engine that's more willing to gain the revs. Thus we get sooner to the best fuel efficiency range.

Although, the timing is retarded typically on ly 1-2 degrees for the emissions (also Cummins has to make sure to deliver the best possible mileage. What about a new word? Emissions possible mileage?) which leads from my findings to a 1.5-2% mileage loss.

To come to a conclusion. The timing alone gains about 2% mileage. This nets out to nothing that could be measured in the real world! Yet, the timing (engine responsiveness) combined with increased fueling in order to get into the best BSFC range as soon as possible is what really gains mileage!

This is the real reason why most customers report mileage gains with their power modules. They get to the RPM range sooner and can stay longer where the diesel engine is most fuel efficient.

Do you have a mechanical timing recommendations(s) for '89-'93 VE fuel pumps? The expected mpg benefit?

TST: The '89-'03 engines didn't have to meet as strict emissions rules thus the timing was left in a position for fairly high in cylinder temperatures and pressures. Timing changes would have very little effect on mpg.

MADS: No.

Do you have a mechanical timing recommendations(s) for the '94-'98 P7100 fuel pump? The expected mpg benefit? Data?

TST: Timing was retarded more in '94 to meet the NO_x laws thus advancing timing had more effect on mileage. Though we didn't make dyno runs at constant horsepower to measure fuel economy on our 12-valve truck, my log-book mileage appeared to improve by 3 to 5% once we advanced timing from about 12.5 to 15.5 degrees BTDC. This lowered exhaust temperature a bit at a constant power, and made the engine rattle more.

MADS: No.

Please share your timing experiences with the '98-'02 VP44 fuel system and your performance module. The expected mpg benefit? Part number to be used? Settings for best mpg? Data?

TST: The '98.5-'02 trucks with the VP44 pump had even more retarded timing than the '94-'98 trucks to meet an even lower NO_x standard. We used computer tools to change the numbers in the ECM timing tables and again lowered exhaust temperatures and picked up 3-5% fuel economy in our log-books.

MADS: *Reported* mileage gains with the Smarty S-03 are in the 1 to 3 mpg range. And, although I would like to believe in a 3mpg gain…I have never experienced it personally in my daily driver(s)! I've found that a 1 to 1.5mpg increase sounds more reasonable. There is no such thing as "best" setting for mileage. Everything depends upon driving style and conditions. This is why we strive to deliver to most flexible tuning system possible. "One size fits all" just can not do the trick.

Please share your timing experiences with the '03-'07 5.9-liter HPCR fuel system and your performance module. The expected mpg benefit? Part number to be used? Settings for best mpg? Data?

TST: We ran dyno tests with various timing on our '03 Ram and gained about a 4% improvement in fuel economy at 55mph, up to a 10% gain at 75mph. Book mileage jumped 2-3 miles per gallon on this truck for a 10-15% gain.

MADS: The answer is the same as my response to the question about the VP44 fuel system. The product that should be used in HPCR applications is the Smarty S-06 or SJ.

Your closing comments:

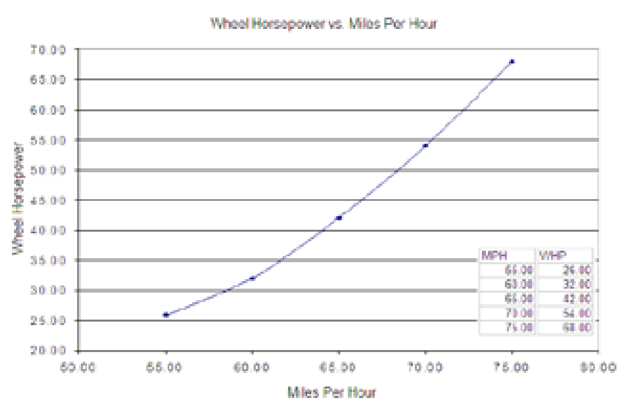
TST: TST has been in the business of increasing power and torque for a decade. Up until 2006 about 90% of incoming started with, "How can I get more of that power and torque stuff?" Then, almost overnight, the question became, "How can I get more mileage out of this big beast?"

Power and torque increases were always easy for us to measure as we test on our own chassis dynamometers. Typically, we would leave one of our test trucks on the dyno for 6-8 weeks at a time, daily trying a program change or parts change, and let the dyno tell us if the engine liked or disliked the change.

My first job in Cummins engineering in 1966 was keeping track of hundreds of test semi-trucks running without ever changing motor oil. Monthly, I would have to pull oil samples on each of these trucks, record mileage, any oil addition since the last check, and document the results of the oil analysis tests. I started keeping record books on my personal vehicles at that time, recording every event, fuel fill, oil change, new tires, etc. As a part of the personal record keeping, I'd calculate the mileage at each fill and noticed how the mileage constantly changed tank to tank. I've continued this practice to present day with my diesel trucks, keeping Excel spreadsheets to show each tank's mileage, running average, and change in fuel cost. Carefully filling the tank to the top, with the aid of a tank vent kit, still did not eliminate the variation tank to tank. My Excel spreadsheets (and your notepad and pencil) are good for long-term trends, but I view them as consistently inconsistent for short-term evaluations.

With customer requests for better mileage becoming the number one priority, I spent many hours wondering how TST could evaluate fuel economy without burning several tanks of expensive fuel. I recalled my experience in the Cummins Engine research labs where we often monitored the fuel consumption of running engines without the hindrance of an attached vehicle. All engine manufacturers gather data to calculate brake specific fuel consumption (BSFC) in order to compare the relative economy or efficiency of various engines. Typically an engine would be run for several minutes at a constant brake horsepower and the fuel used was measured in pounds. The word brake in this case meant the engine dynamometer which measured flywheel torque and engine rpm such that engine flywheel horsepower could be calculated. A simple calculation could be made with the gathered data by dividing the weight of the fuel used in pounds per hour by the horsepower being generated. BSFC number like 0.350 pounds per horsepower per hour was the end result. A very good engine might run a 0.330 BSFC while a poorer engine might run close to 0.410 BSFC.

I felt finding a BSFC-like number for a Turbo Diesel would be a good way to check the relative fuel consumption. I knew our chassis dyno could be set to measure the horsepower at the wheels. But at what horsepower did we need to run the tests? The TST staff brainstormed the question and decided we needed to determine the actual horsepower it took to move a Turbo Diesel pickup at various road speeds. We took our '03 Dodge Ram out on the Interstate highway and ran it for several miles in both directions while recording instrument readings for air temperature, mph, gear selected, turbo boost, egt, rpm, and rail pressure. We gathered data for road speeds from 55 mph to 75 mph, in 5 mph increments. We then tied that truck to the chassis dynamometer and tried various loads until we could reproduce the instrument readings we took out on the Interstate. This gave us a horsepower value to use in our fuel economy tests for various road speeds. (See figure 1)



Next, we needed a way to accurately measure the fuel used during our testing. While we considered trying to carefully refill the stock Dodge fuel tank after each run, we quickly discarded that idea because it was impossible to fill that tank to the same level each time. We also considered placing a small tank in the bed of the truck that would be easier to refill to the same level each time, but that still left us with the problem of measuring just how much fuel it took to refill the tank. Suddenly it became obvious, let's run the truck using a remote fuel tank that sets on a very accurate scale and simply weigh the fuel as it is consumed. By carefully weighing a gallon of fuel, we could then determine the number of pounds per gallon. We could then use this pounds-per-gallon number to convert our pounds of fuel used back to gallons for the mpg calculation. This is the procedure that is used by Cummins in official ASE-type testing of big rigs at fleet accounts. We purchased an electronic scale with a digital readout that was guaranteed accurate to one hundredth of a pound and used a transparent five-gallon plastic jug as our fuel tank. We unhooked the quick connects from the truck tank and plumbed them such that the engine would draw and send its return fuel to the plastic jug (See picture below).

Ready to start testing? We thought so. We brought the truck up to 55mph on the dyno and set the truck cruise control to hold the speed. That part worked great. Next we started increasing the load on the dyno until we could repeat the horsepower number we found from the earlier Interstate highway testing. That part worked great too. Then we drove the truck for five minutes at these conditions taking the fuel weight before and after the test. That part worked great too. Well, almost. One of our technicians accidentally touched the five-gallon jug and realized it had become very hot from the engine's returned fuel.

It took about four hours to add 50 feet of copper tubing to our return fuel line. We dropped that copper line into a large cooler and returned the fuel to the plastic jug. We then used a garden hose to run cold city water through the cooler to keep the returned fuel cool. By regulating the city water flow we could maintain the fuel temperature at a usable level.

We were ready to start testing again. This time we were able to repeat the weight readings time after time during the five-minute test. We now felt we had a way to quickly and accurately determine how various engine changes would affect fuel consumption.

Back in 2002-2004 we developed the PowerMax CR for the 5.9 HPCR engine. We engineered a way to vary injection timing, injection duration, and rail pressure on the fly. Of course our motive was different back then; we were after the most power and torque at the lowest exhaust temperature. Now with a new goal of best fuel economy, we started all over again trying to optimize timing, duration, and rail pressure.

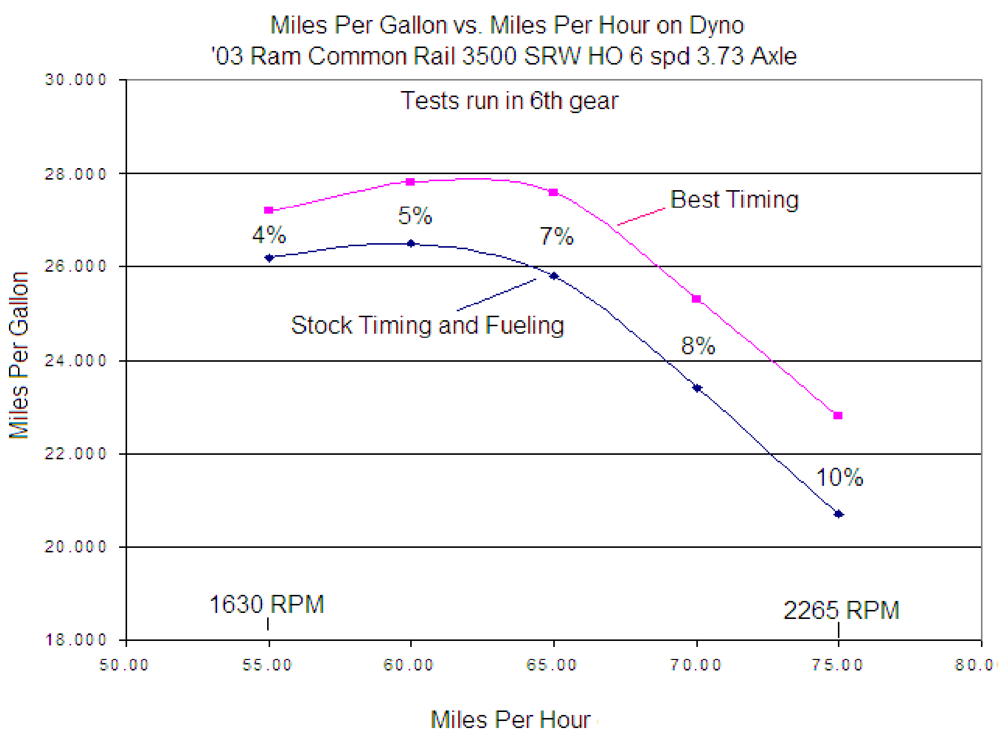
First we determined the fuel consumption curve for the stock engine using our new measurement method. (See lower curve in figure 3.) The mileage numbers from this test were quite a bit better than our record book showed for this truck, but keep in mind that our new test method was steady state only, no starting and stopping. I figured if we could improve the steady state numbers, mileage would also improve on the highway.

To start, we tried the injection timing schedule from the PowerMaxCR that gave us the best power curve. That timing helped fuel economy a bit, but not a significant difference. Over the next few hours we tried many different injection timing settings and selected the ones that gave us best economy from 55 to 75 mph. (See upper curve in figure 3.) We then tried varying the rail pressure while using only the best timing found earlier. Changing the rail pressure didn't help.

We added an "Economy" setting to the PowerMaxCR as a result of these tests. To date, customer experience has been mixed. Some claim big gains like 3 to 4mpg, some report no change at all, while a few claim they lost mileage. How could this be? Looking back, all testing was done on the same truck. The truck was a '03 Quad Cab, 4x4, SRW, long bed, six-speed manual, 3.73:1 axle, stock BFG tires (LT 265/70 R17). The only modifications to the truck were cab high full length cap, FASS HPFP 95 gph pump, and a South Bend Double Disc clutch. I felt the FASS pump and SBC clutch had no affect on the mileage test, but were needed on the truck for full power testing done separately.

What next? Let's run the rail pressure box but with stock timing. Bigger injectors get the fuel in quicker, so do they help the same as advancing timing? How about a 48RE automatic truck? Is there any difference in the behavior of the '04.5 HPCR engine with its 325hp? I've got a 6.7-liter chassis cab to test. Then there is the 6.7-liter pickup with the terrific new 68RFE six-speed automatic. What? You want me to run an '89, too. It doesn't end, does it.

Maybe next issue!
Mark Chapple
TST Products



FUEL MILEAGE

The big concern today is fuel mileage, in deference to the high prices we are paying. Some useful information was presented in "The Way We Were" in TDR Issue 47, pages 103-107. That article was a reprint of information from way back in Issue 29, but the concepts are still valid today and more worth reviewing than ever. Most recently, I discussed fuel mileage versus performance in Issue 60, page 90. Fuel is up another dollar or so a gallon since then, so many readers are even more concerned. Let's just briefly hit the high points.

Watch out for unnecessary added weight. It takes fuel to carry or pull more weight. The Third Generation Turbo Diesel in your driveway may be 1000 pounds heavier than your old Second Generation Turbo Diesel was. My '04 has a shipping weight of over 7000 pounds versus 6000 for my '97. The extra 700 pound load of fuel you carry in an auxiliary fuel tank costs a bit of mileage also!

Wind resistance can be increased by added toys such as big tires, poorly designed aftermarket front bumpers, and aftermarket accessories such as brush guards, mirrors and bug deflectors. Winter fuel has a lower heat content (usually measured in British thermal units or BTU) so will often cost 1-2 miles per gallon (mpg). Synthetic or premium lubricants can help mileage a little. Injectors can play a role in improving economy. Owners of the '98.5 to '02 24-valve Turbo Diesels report an improvement of about 1.5 mpg from the Bosch #0432193635 injectors that were originally used on the 275hp rated RV engines. Of course, driver habits remain one of the biggest, if not the biggest, factor in fuel economy.

One personal experience regarding driver habits is worth noting here. Running 79mph on the interstate over long trips used to be normal. However, reducing speed to 72-74mph gained me some mpg, maybe 1 or more.

Moving on from what toys or features on your truck may be hurting, and how your heavy right foot plays a role, let's consider what we can do to the engine itself. Probably one of the biggest improvements we can make is advancing the timing toward "best economy" settings rather than the "best emissions" that the factory has to adopt. Cummins is aware of the trade-offs, and summarizes the effects of moderately advanced timing as these:

- Increased cylinder temperatures and pressure (more power)
- Increased fuel economy
- Decreased exhaust temperature
- Decreased hydrocarbon emissions
- Increased smoke at peak torque
- Increased NO_x emissions.

The hardest emissions parameter to bring down to the EPA legislated levels for diesels is NO_x and that is the culprit behind the retarded timing and the exhaust gas recirculation (EGR) systems that hurt diesel fuel economy so much. In this issue we will focus on ways to advance the injection timing on your Turbo Diesel.

Editor's note: Numerous times I have been chided for not adding the legal disclaimer prior to a writer's article that discusses a performance gadget, gizmo or modification. Changing the timing of the fuel delivery is a modification that "can put your rights to warranty consideration into serious jeopardy. Additionally, the timing changes 'must not adversely affect emissions' according to the Clean Air Act, Section 203(a) and EPA Memorandum 1A."

There you go. If you want the full details of the warranty and emissions discussion you should refer to Issue 60, page 50-52. And the answer to "Why didn't the factory guys do this?" is addressed on page 42.

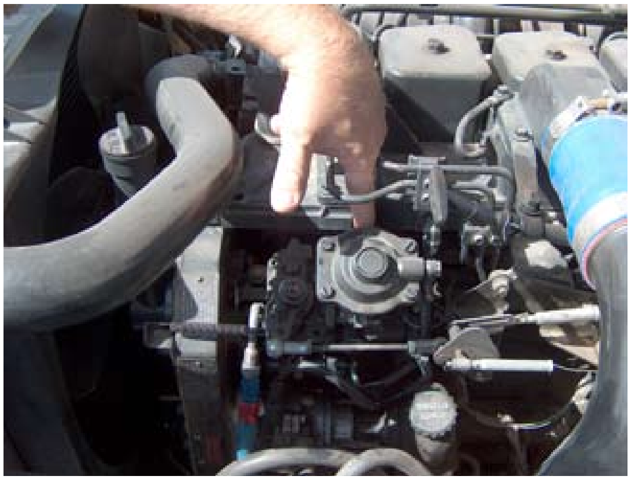
SETTING THE ENGINE'S TIMING

Timing the Bosch VE Injection Pump ('89-'93 Vintage)

The VE distributor type injection pump came out in the 1970s and was used in the Dodge Turbo Diesel application from '89 up through the '93 model year. This pump has been widely used for diesel engines up to about 33 horsepower per cylinder output (about 200 hp for six cylinder engines). It weighs only about ten pounds and is relatively compact in dimensions. It is moderate in cost to buy and to repair. It is lubricated by diesel fuel only, so it is very sensitive to fuel quality. Its maximum design output fuel pressure is 700 bar (10,150 psi). It uses a single high-pressure piston, so it has fewer parts than many other designs of pumps. Idle speed, maximum speed, and maximum fuel delivery quantity are all externally adjustable. Tamper-resistant caps or seals are put over the adjustment screws at the factory.

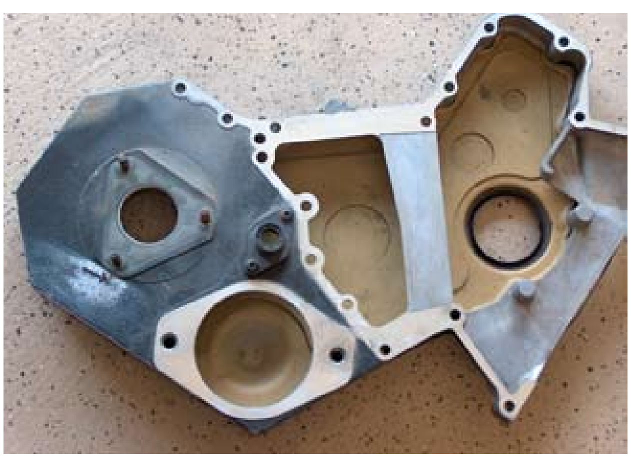
The VE pump is limited in fuel delivery volume and pressure, compared to the pumps used in later model Turbo Diesels. The volume limitation became important when greater horsepower was sought. The low (10,000 versus 17,000 psi) pressure meant that new emission regulations for 1994 could not be met. To meet these EPA regulations, higher pressure was needed to bring in enough fuel quickly, during the time period when it would burn most efficiently and produce the least smoke. Higher pressure also improved atomization, especially if larger injectors were used to increase fuel delivery for more power. In the early 1990s, these concerns were coupled with problems from the advent of low-sulfur fuel, and with the concerns about poor fuel quality or cleanliness. These issues made it clear to the manufacturers of diesel engines that they had to discontinue use of the VE pump for our Turbo Diesels and for other over-the-road applications.

There are official tools and procedures for setting the timing of the VE pump. Many years of working with these pumps on Dodge applications have resulted in some "quick and dirty" procedures that you can use on a try-and-fit basis. You can try small incremental positioning (turning) of the pump to see what effective timing works best for your truck. If you want to take the pump timing about as far advanced as you would want, for good performance and economy, the result will be around 5/8" to 3/4" clearance between the air-fuel control module (afc) and the cylinder head, about a finger-width. Advancing the pump too much (moving the top toward the head) gives white smoke, but not the amount of engine fuel knocking or rattling that you would get from advanced timing with an in-line P7100 pump. Better mpg may occur with advancing the VE pump timing slightly from stock. Retarding the pump timing will generally result in lower engine power.



A Bosch VE pump on a Cummins B engine, with a finger showing the clearance between the AFC module and the cylinder head.

If you decide to use the "finger clearance" method, first look closely at the pump flange to the outside of the outermost mounting stud and nut. You should find a chisel notch on it, and a corresponding notch in the gear housing. These marks serve to indicate the "factory" timing setting. To rotate the pump and advance the injection timing, you need to loosen the three 13 mm headed nuts and the injector line nuts at the back of the pump (so you won't twist the lines and strain them). The pump will resist turning until the nuts are loose enough, because of the fiber mounting and sealing gasket that can be seen in the photos. The Snap-on Blue Point SP144 wrench helps greatly in removing the two hard-to-access pump mounting nuts. The Snap-on flare nut crow's-foot helps to loosen the injector line nuts. It should be 16 mm (5/8", part number FRH200S) or 17 mm (part number FRHM17).



Engine side of a VE-pump style Cummins gear housing.

Close up view of the VE pump mounting area of the gear housing with the housing timing mark and the pump-to-housing gasket.

Snap-on flare nut crow's-foot and pump mounting nut wrench.

This article was an update of Joe's Issue 35, page 20-21, article on the Bosch VE fuel injection pump.

Timing the Bosch P7100 Injection Pump

The Bosch P7100 in-line injection pump is heavy (about 45 pounds), large, relatively expensive to buy and to repair, and originally intended for much larger engines than our little 5.9-liter Cummins B series. This model of pump ended up on the '94-'98 12-valve Turbo Diesels. Dodge and Cummins were able to increase power ratings without stressing the capabilities of the pump. They could meet the new, more stringent emissions requirements of January, 1994 because this pump had the fuel volume and especially the pressure they needed. This pump is intended for original equipment manufacturer's applications up to 94 hp per cylinder (563 hp for six cylinders) and produces fuel pressures up to 1150 bar (16,675 psi). Like the VE pump, it is fully mechanical in operation, but there the similarity ends.

The P7100 pump is an in-line design pump. This means that the injector for each cylinder of the engine is fed by a dedicated high-pressure plunger-and-barrel assembly in the injection pump. These plunger-and-barrel assemblies are arranged in a linear fashion, not a circle. The fuel is pressurized by the up-and-down stroke of the plunger, brought about by a camshaft eccentric (see Figure 4). Thus this pump has a camshaft that is engine-driven, and each plunger has a roller-lifter type of actuation. Fuel delivery quantity is controlled by rotating the plunger. This action changes the exposure of the fill/spill port of the barrel to the fuel gallery, to determine the amount of fuel that will be "trapped" and pressurized. (See Figure 5). The six plungers (for a six-cylinder diesel engine) are connected to a fuel control "rack" which extends to the governor so that the governor can control the fueling of all six plungers equally and simultaneously.

For different power ratings, Bosch uses different design plungers and barrels, and different camshaft lobe profiles. For our Turbo Diesels, there are three basic internal sizes of P7100 pump: The 160hp is the smallest; the 175-180hp is somewhat larger, and the 215hp version is one of the largest P-pumps available. For comparison, using Turbo Diesels that are otherwise similar in level of modification, The 160hp pump would allow about 320-340hp at the wheels, the 180hp pump would give about 370-400, and the 215 pump would give 500-540hp. All of these pumps use versions of the Bosch Model RQV-K governor.

The P7100 uses engine oil to lubricate the governor and bottom end of the pump. Of course, the fuel plungers and barrels, as well as the delivery valves, still rely upon diesel fuel for their lubrication, so it would be a serious mistake to think that any type of diesel fuel is adequate because the pump uses engine oil as a lubricant. The pump is generally very reliable, and being fully mechanical in operation, it is relatively easy to diagnose and to modify.

Back in 1999 when I was taking a lot of long trips, I found that 15 to 15.5 degrees of injection pump timing advance on the 215hp engine gave the best fuel economy at about 2000 rpm. I ran as much as 19 degrees and did not have any headgasket or starting issues.

To set the timing of the P7100 pump, you need precision tools and all fuel system internal parts must be kept scrupulously clean. You need Miller MLR 6860 pump timing tool kit and a Snap-on Blue Point SP504 plate style gear puller (or equivalent). When you remove the #1 delivery valve, do not touch it dry with bare fingers. Use a clean telescoping stalk/magnet and keep it covered with clean diesel fuel.

T5. Miller MLR-6860 P7100 pump timing tool kit. At the left is a magnet on a telescoping "stick." To its right is the dial indicator with the stem extension below and to its right. To the right of that is a timing pin with a steel tip epoxy glued onto it. The special splined socket is at bottom right, with the splined end resting on a block of wood. At top center is the adapter that holds the dial indicator and screws into the top of the pump barrel. At top right is an engine barring tool that plugs into the aluminum block adapter plate and meshes with the flywheel teeth.

T6. The Snap-on SP504 gear puller with M8x1.25x40 bolts and the home-made pump shaft turning tool at right.

The P7100 injection pump cannot be simply rotated so the top is closer to the cylinder head. Its mounting ears do not have elongated slots, and the back end of this very heavy pump is supported on a flat pedestal mounted to the engine block. You must pull the drive gear and then rotate the pump shaft. Pulling the gear inevitably results in a shock as the taper fit "pops," causing the pump shaft to jump out of time, in the retarded direction—but how much it jumps (rotates) varies with each time it happens. That is why you simply CANNOT use a shadetree trick like popping off the gear, turning the crank a little, and replacing the gear. You just cannot tell where the pump timing "went" without the dial indicator.

We will go through the principles and procedures for setting P7100 pump timing, but the cost of the tools and the advanced type of effort involved make it neither realistic nor cost effective for most Turbo Diesel owners to do this at home.

Principle behind mechanical fuel injection timing

In a four-cycle gasoline engine, the distributor and the camshaft both turn at one-half crankshaft revolutions per minute (RPM). Since diesel fuel is ignited upon injection, a fuel injection pump for a four-cycle diesel engine also rotates at one-half engine rpm. The 36-tooth crank gear turns the camshaft gear which has double the number of teeth (72) on it that the crank gear does. In turn, the cam gear turns the Bosch P7100-pump drive gear which also has 72 teeth so the pump will inject fuel every second revolution of the crank (or top dead center position of the piston). Timing of the pump and this injection event is controlled by the design of the pump and the rotation/position of the pump shaft (with its eccentrics that control the fuel "squirts" to the injectors) versus the position of the crankshaft (and hence the piston). The pump gear is solidly attached to the pump shaft by a Morse taper fit similar to the taper fit that holds the drill chuck to the spindle of a drill press. To advance the pump timing, you need to pull the gear off the pump shaft, rotate either the gear or the shaft, and clamp them back together so that the pump shaft reaches a point where the fuel injection squirt comes sooner relative to the movement of the crankshaft and piston.

Procedures to re-set the timing with the P7100 pump

1. Install a dial indicator so you can track the fuel injection event within the pump. Install the engine barring tool in the flywheel and rotate the engine crankshaft until the needle indicates the lowest point of the pump plunger. To get to the plunger, you have to remove #1 injection line, [right hand arrow in photo T7] use a special splined socket to remove the "tower" on the #1 pump barrel, and then use a magnet-on-a-telescoping-stick to pull the delivery valve and its steel casing (about 5/8" diameter) out of the pump barrel. [see photo T8] Then you thread on a special holder for the dial indicator, and install the indicator so the measuring stem is on top of the plunger. [see photo T9]

T7. A Bosch P7100 pump on a Cummins B engine, with arrows pointing to the oil filler tube/cap, and to #1 injection line and pump barrel.

T8. Delivery valve parts removed from #1 injection pump barrel assembly in order to set timing.

T9. Dial indicator installed in #1 barrel of a P7100 injection pump.

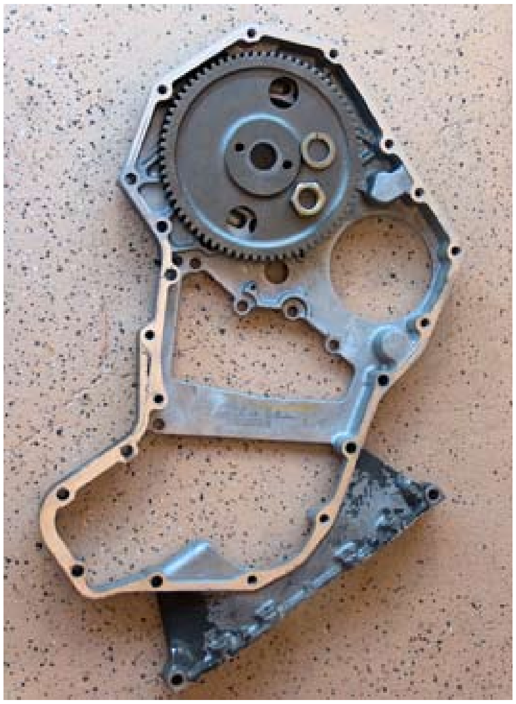
2. Rotate the engine crankshaft to TDC for #1 cylinder and make sure it is the TDC of injection (with a four cycle engine, one is injection/firing TDC and the other TDC is "overlap" of the exhaust and air intake events). The correct TDC will have #1 valves closed and both valves for #6 cylinder will be slightly open.

3. Compare the amount of plunger lift at TDC to timing in degrees using the table on page 105 for the specific version of your P7100 pump. Now you know what the timing is before you reset it.

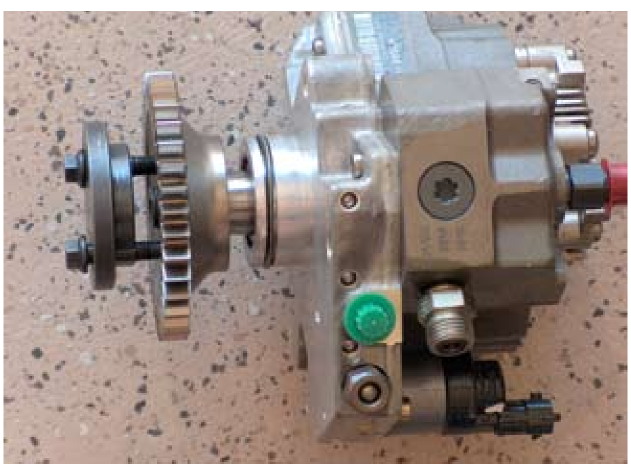
4. While the barring tool prevents the engine from turning, remove the 30-mm hex nut and washer from the pump shaft. The nut is behind the oil filler tube (left hand arrow in photo T7, and bottom left in photo T10), and to access it you have to unthread the oil fill pipe from the base, and unthread and remove the base from the engine gear housing cover (T10).

T10. A Cummins gear housing, front side, with the oil filler tube at yop left.

5. Use a puller (Snap-on SP504 or similar) to “pop” the gear (photo T11) loose from the tapered pump shaft. If you watch the big and little dials of the indicator, you will see how much the pump timing retarded on this occasion. Use of the puller is illustrated on a CP3 pump and gear in Photo T12. (Notice that the CP3 uses a small 36 tooth gear and thus spins at crankshaft speed, not camshaft speed!)



T11. A Cummins B gear housing with a P-pump drive gear, washer, and nut.



T12. Use of the SP504 gear puller is illustrated here with a Bosch CP3 pump.

6. Now you need to turn the pump shaft so the dial indicator gives the plunger lift specification you want, corresponding to the desired timing. You can do this by reinstalling the pump gear and snugging the nut, then using the barring tool to turn the engine and hence the pump. If you are lucky and go to just the right amount of lift beyond what you want, when you pop off the gear, the pump will jump (retard) to the lift you want. The jump should be small if the gear was on just enough to turn the pump, but not very tight. Then you turn the engine back to TDC while leaving the pump gear loose so the pump stays at the timing you want. Use Mopar non-chlorinated brake cleaner #4897150AB to gently spray the taper fit of the gear and shaft while wiggling the gear with a long M8 x 1.25 thread bolt so all the taper is cleaned. Don’t spray hard and blow oil out of the bearing on the pump shaft just behind the taper! Then, gently blow-dry the taper with clean compressed air. Push the gear onto the shaft, install the oiled washer and nut, torque to 144 ft-lb.

7. Here is a tip that may be worth trying if you are going to set timing a number of times: you can weld a ¾” fine thread nut onto an extra P-pump nut, and run a bolt in to jam against the end of the pump shaft. (Photo T6, right side, page 103). Then you can turn the pump to set plunger lift, and hence timing, with this tool and leave the engine at TDC.

8. Check the green O-ring on the “tower” for abrasion and replace it if necessary (Bosch #2 410 210 033). A worn O-ring seal will allow fuel to leak out during operation. Put a thin film of grease on the O-ring and the surface of the pump barrel and tighten the the “tower to 29 and then 85 ft-lb in a smooth motion.

9. Re-assemble, tightening injection line nuts to about 25-28 ft-lb.

The table below shows injection timing in degrees versus injection pump #1 plunger height (lift) for different Bosch P7100 in-line injection pump used from ‘94 through the first half of the ‘98 model year. The engine’s data tag will show the stock timing in degrees and the plunger lift can be measured. Using the table you’ll find the lift necessary to set the timing to achiee better fuel economy. Over time, we have found that about 15.5 degrees of timing gives most folks the best fuel economy but a bit less mid range torque than the stock, lower, timing settings. Your engine CPL can be found on the data tag that is riveted to the driver’s side of the front gear case. The table shows timing in degrees versus millimeters of cylinder #1 pump plunger lift:

Deg.	'94-'95 P7100 injection pumps Automatic	Manual	'96-'98 P7100 injection pumps Automatic	Manual
12.5	4.2	5.7	4.21	4.89
13	4.3	5.8	4.29	4.98
13.5	4.4	5.9	4.37	5.07
14	4.5	6.0	4.45	5.16
14.5	4.6	6.1	4.53	5.25
15	4.7	6.2	4.61	5.34
15.5	4.8	6.3	4.69	5.43
16	4.9	6.4	4.77	5.52
16.5	5.0	6.5	4.85	5.61
17	5.1	6.6	4.93	5.70
17.5	5.2	6.7	5.01	5.79
18	5.3	6.8	5.09	5.88
18.5	5.4	6.9	5.17	5.97
19	5.5	7.0	5.25	6.06
19.5	5.6	7.1	5.33	6.15

Timing the VP44 Fuel Injection Pump

The Cummins 24-valve engine was designed to meet the tighter EPA federal emissions regulations of January 1998. An essential feature of this engine was the use of electronically-controlled fueling events. The Bosch VP-44 injection pump (see Figure 10) was already in use in Europe for smaller engines, and was fully electronically controlled with regard to injection timing and fuel quantity. This pump delivers fuel at high pressure (1000 bar or 14,500 psi), almost as high as the P7100, to assist in meeting emissions requirements. The size, weight, and cost of the pump are much lower than the P7100, more like the VE pump. However, the new VP44 pump differs in several important respects from the older pump. In order to develop the higher pressure it produces, it uses three radial pistons to pressurize fuel instead of one axial piston. While the engine mechanically rotates the pump, as with a VE pump, the fueling commands are all performed via on-board computer (fuel pump control module). While there are different Woodruff keys for the VP44 pump shaft, you cannot advance the pump timing with them. The computer will normalize the timing to specification.

As soon as the 24-valve Cummins engine appeared with our Turbo Diesels, in January 1998, some owners of the new version of the Cummins B series engine began complaining that they wanted more power. Several aftermarket companies addressed the problem and found that electronic solutions were the most straightforward to develop and install. Some of the power-adding products also added timing advance. The VP44 injection pump is mechanical but is surrounded by three computers. First is the Dodge computer on the firewall, second is the engine electronic control module (ECM) on the driver's side of the engine, and third is a computer on the top of the VP44 pump itself. The ECM has proprietary software controlling the fueling parameters, and the fueling commands are sent to the VP44 computer through CAN-BUS communication protocols. The electronic enhancements made by aftermarket firms have used one or more of the four techniques listed below:

1. Intercept the CAN-BUS communications to the VP44 computer at the multi-connector that plugs into the pump. This process entails unplugging the connection, and putting in a Y-connector that goes to the aftermarket "black box" computer. This add-on computer then replaces some commands from the ECM with new ones. One brand (example) that uses this technology is the BD Plug-n-Power.

2. Add new instructions along the CAN-BUS using the data link/diagnostic connector at the engine wiring harness. This connector is used by Dodge and Cummins technicians to access the ECM for engine diagnosis, and to reprogram the ECM. The Edge Products EZ box uses this system, and their Competition Box uses both this technique and Technique #3.

3. Intercept the fueling signal coming out of the VP44 computer that holds the fuel solenoid of the pump closed. This signal determines the time duration that high pressure fuel is available to the injection line and injector. The insulation of this wire is pierced by a Scotch-Lok or similar connector so the add-on aftermarket computer box can receive this signal and add another immediately afterwards to hold the solenoid closed longer. The percentage of the original signal's time duration that is added to it by the aftermarket computer box will determine the power increase. This technique was introduced by Blue Chip, then followed by a similar approach from TST, and later Edge Products.

4. Reprogramming the ECM fueling and/or timing advance curves.

Techniques 1, 2 and 3 require an additional wiring harness to the manifold absolute pressure (MAP) sensor on the side of the cylinder head at the intake plenum, if they are to provide large power (fueling) increases. The ECM generates defueling commands when turbocharger boost goes too high (reportedly, over 20.5 psi). The aftermarket computer harness puts a Y-connection into this harness at the MAP sensor. The box intercepts the boost signal and replaces the signal going to the ECM with an adjusted voltage that indicates to the ECM that boost is within the acceptable range, even when higher boost is actually present. In this way, sufficient boost becomes available to burn the additional fuel efficiently.

Add-on "boxes" that use Technique 3 take the engine rpm and ECM-generated fueling level signals from the pump wire. Boxes that receive CAN-BUS signals, including the

Edge Comp box that uses both Techniques 2 and 3, take rpm and fueling commands from signals along the CAN-BUS.

Electronic power enhancement “boxes” that also add timing include, among others, the Edge Mileage Max and the Juice module with Attitude gauge and control readout box.

The Smarty programmer gives the option of adding timing in its re-program of the ECM (Technique 4).

Timing the High Pressure Common Rail (HPCR) Engines

With the HPCR system, timing is electronic. The pump does not “squirt” fuel at the proper time into a single injection line. High pressure fuel is available at all the injectors all the time the engine is running. The injectors are opened and closed electrically when the engine control module (computer, ECM) commands. There is a mechanical timing sensor on the market that basically moves the crank sensor a little. However, it cannot move much from stock position or the cam to crank sensor alignment will be outside of specifications allowed by the ECM and the engine will not start or run. Significant timing changes must be made electronically, either by a remote box or through ECM programming.

Electronic power enhancement “boxes” that add timing include, among others, Edge and TST boxes. The Edge Mileage Max and the Edge Juice module with Attitude gauge and control readout box. The TST PowerMax-CR allows the user to select the default additional timing, or to add further timing advance in increments of 3 degrees.

The Smarty programmer gives the option of adding timing in its re-program of the ECM. In addition to the default timing increase, the user can select additional increases in the options menus of the Revolution and TNT software packages.

Editor’s note: TDR writer Doug Leno has done extensive research on performance modules for the ’03-’07 5.9-liter HPCR engines. His work is chronicled in TDR Issues 45, 47, 48, 49, 51, 53 and 57. When asked about fuel mileage (rather than performance) he referred me to his comments in Issue 51, February of 2006.

Doug Leno’s Conclusions

- Depending on driving conditions and style, fuel economy improvements on the order of 10% can probably be obtained with a combination of pressure and timing advance. Products offering this approach include the Banks Six Gun, the Quadzilla Xzillaraider, TST Products’ PowerMaxCR, and likely (though I haven’t tested them) the towing programs offered by the various downloaders from Bullydog, Pacific Performance Engineering, ATS, Smarty and others.
- Traditional pressure modules, even without a connection to the cam/crank sensors or the CAN bus, probably yield some fuel economy benefit, but not as much as a true pressure/timing enhancement will.
- Timing only, as provided by the TST PowerMax CR (power level 1) will also improve fuel economy. However, realize that it requires discipline to use such a powerful module set at only 25 horsepower gain over stock!
- Never install a power enhancement from any manufacturer without addressing other areas of the truck that may require attention in order to use the additional power. In particular (and most important) you must install an EGT gauge (pyrometer) and keep pre-turbocharger exhaust gas temperatures under 1350°.

Joe Donnelly
TDR Writer

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Edge Products
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www.edgeproducts.com

Bob Wagner and Associates
888-225-7637
www.smartypower.com
www.madselectronics.com

YOUR TRUCK AND THE BOOST TREADMILL

Boost specifications: The TDR magazine has often been criticized for being too technical, I should take an opportunity to explain why the maximum boost specification is important to an owner.

I searched the archives for an easy-to-understand article on turbocharger boost. The following is a quick review of turbocharger basics.

TURBO BASICS

The principle behind a turbocharger is simple: get more power from the engine without increasing the engine's size.

To increase engine power, you start by adding more and more fuel. But soon, you'd be wasting fuel, because the fuel needs air to burn. Technically, it needs the oxygen in the air to burn.

In a naturally aspirated engine, the air is pulled from the atmospheric pressure surrounding the engine into the combustion chamber on the intake stroke of the cycle.

At sea level there are .016 pounds of oxygen per cubic foot. At higher altitudes, air is thinner and there's less oxygen. For example, at 5,000 feet there's only .010 pounds of oxygen per cubic foot. So, at higher altitudes there's a greater demand for air to supply an engine with oxygen. A turbocharger is the solution.

In the simplest of analogies, think of a turbocharger as two pinwheels connected, back-to-back, via a common shaft. As you blow on one wheel, the other wheel turns too.

Inside a turbocharger, exhaust gases flow out of the combustion chambers into the turbine housing. The exhaust gas is channeled to the pin wheel, causing the pin wheel "turbine" to rotate.

The turbine wheel turns a common shaft which is connected to a pin wheel on the fresh air side of the turbocharger, known as the "compressor."

The compressor wheel blades draw filtered air into the compressor housing, raising the air's density and pressure, as the air is forced into the engine. More air mixed with more fuel equals more power.

As you add air/fuel to the engine it makes more power. The temperature and flow of the exhaust gas increases. With the increased exhaust flow and temperature, the exhaust pin wheel (turbine) spins faster. Thus, the intake pin wheel (compressor) pressurizes (boosts) more air into the engine. More air/fuel to the engine makes more power, creates additional exhaust flow and temperature... Get the picture?

BOOST DIAGNOSTICS

How can we use the engine's "boost" to diagnose engine performance? There are specifications for boost for the various engines which have been and are in current production. Keep in mind that it takes fuel and air to make power and boost. If the engine meets the boost specification, the power is there and it passes the "Boost Treadmill test."

At this juncture it is tempting to generalize the data. However, I'll avoid the temptation and research the boost specification for a given engine build or, in Cummins-speak, control parts list (CPL). The Cummins CPL is a number that spells out key components (fuel pump settings, turbochargers, cylinder heads, pistons, etc.) used in the engine. The following detailed table presents the data.

Model Year	HP@RPM	Torque @ RPM	CPL	Transmission	Comments	Boost Specification
'89 – '91	160@2500	400@1600	804	Auto/Manual		22-25
'91.5 – '92	160@2500	400@1600	1351	Auto/Manual	Mid-year intercooler	15-19
'92.5 – '93	160@2500	400@1600	1579	Auto/Manual	Mid-year change	15-19
'94 12-Valve	160@2500	400@1600	1815	Auto		15-18
	175@2500	420@1600	1816	Manual		15-18
'94.5 12-Valve	160@2500	400@1600	1549	Auto	Mid-year catalyst	15-18
	175@2500	420@1600	1550	Manual	Mid-year catalyst	15-18
'95 12-Valve	160@2500	400@1600	1959	Auto		15-18
	175@2500	420@1600	1550	Manual		15-18

Model Year	HP@RPM	Torque @ RPM	CPL	Transmission	Comments	Boost Specification
'95.5 12-Valve	160@2500	400@1600	1968	Auto	mid-year change	15-18
	175@2500	420@1600	1550	Manual	mid-year change	15-18
'96 12-Valve	180@2500	420@1600	2022	Auto	EPA	19
	215@2600	440@1600	2023	Manual	EPA	25
	180@2500	420@1600	1863	Auto/Manual	CARB-Catalyst and EGR	19
'96.5 – '98 12-Valve	180@2500	420@1600	2174	Auto	EPA	19
	215@2600	440@1600	2175	Manual	EPA	25
	180@2500	420@1600	2308	Auto/Manual	CARB-Catalyst and EGR	19
'98.5 24-Valve	215@2700	420@1600	2098/2513	Auto	EPA	18
			2280/2515	Auto	CARB	18
	235@2700	420@1600	2024/2512	Manual	EPA	18
			2279/2514	Manual	CARB	18
'99 24-Valve	215@2700	420@1600	2617	Auto	EPA	18
			2619		CARB	18
	235@2700	460@1600	2616	Manual	EPA	18
			2618		CARB	18
'00 24-Valve	215@2700	420@1600	2660	Auto	EPA	18
			2661		CARB	18
	235@2700	460@1600	2662	Manual	EPA	18
			2663		CARB	18
'01 24-Valve	235@2700	460@1600	2865/2902	Auto	EPA	19.5
			2866/2903		CARB	19.5
			2496/2904	5 Manual	EPA	19.5
			2497/2905		CARB	19.5
	245@2700	505@1600	2415/2906	6 Manual	EPA	19.5
			2495/2907		CARB	19.5
'02 24-Valve	235@2700	460@1600	8030	Auto	EPA	19.5
			8031		CARB	19.5
			8032	5 Manual	EPA	19.5
			8033		CARB	19.5
	235@2700	505@1600	8034	6 Manual	EPA	19.5
			8035		CARB	19.5
'03 5.9 HPCR	235@2700	460@1400	8216	47RE Auto	CARB – Catalyst equipped	23
			8224	5 Manual	" " "	23
	250@2900	460@1400	2624	48RE Auto	EPA – Non-Catalyst	23
			8223	5 Manual	" "	23
	305@2900	555@1400	2998	6 Manual	" "	26

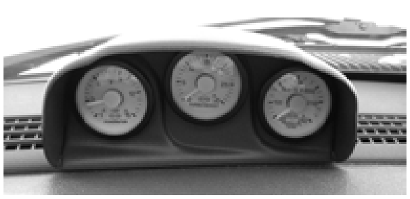
Model Year	HP@RPM	Torque @ RPM	CPL	Transmission	Comments	Boost Specification
'03 5.9 HPCR	235@2700	460@1400	8216	47RE Auto	CARB – Catalyst equipped	23
			8224	5 Manual	" " "	23
	250@2900	460@1400	2624	47RE Auto	EPA – Non-Catalyst	23
			8223	5 Manual	" "	23
	305@2900	555@1400	2998	6 Manual	" "	26
'03.5 5.9 HPCR	235@2700	460@1400	8410	48RE Auto	CARB – Catalyst equipped	23
			8412	5 Manual	" " "	23
	250@2900	460@1400	8212	48RE Auto	EPA – Non-Catalyst	23
			8226	5 Manual	" "	23
	305@2900	555@1400	8228	6 Manual	" "	26
			8213	48RE Auto	" "	26
'04 5.9 HPCR	235@2700	460@1400	8412	48RE Auto	CARB – Catalyst equipped	23
			8412	6 Manual	" " "	23
	305@2900	555@1400	8213	48RE Auto	EPA – Non-Catalyst	26
			8228	6 Manual	" " "	26
'04.5 5.9 HPCR	325@2900	600@1600	8350	6 Manual	EPA – Catalyst equipped	30
			8351	"	CARB " "	30
			8346	48RE Auto	EPA " "	30
			8347	"	CARB " "	30
'05 5.9 HPCR	325@2900	610@1600	8423	6 Manual	EPA – Catalyst equipped	30
			8424	"	CARB " "	30
			8421	48RE Auto	EPA " "	30
			8422	"	CARB " "	30
'06 5.9 HPCR	325@2900	610@1600	8348	6 Manual	EPA – Catalyst equipped	30
			8349	"	CARB " "	30
			8344	48RE Auto	EPA " "	30
			8345	"	CARB " "	30
'07 5.9 HPCR	325@2900	610@1600	1091	6 Manual	EPA – Catalyst equipped	30
			1095	"	CARB " "	30
			1000	48RE Auto	EPA " "	30
			1083	"	CARB " "	30
'07.5 6.7 HPCR	350@3000	610@1600	8233	6 Manual	EPA	28*
			8234	"	CARB	28*
		650@1600	8230	68RFE Auto	EPA	28*
			8231	"	CARB	28*
'07.5 6.7L Cab/ Chassis	305@2900	610@1600	8232	6 Manual	EPA	26*
			1264	"	CARB	26*
			2885	Aisin Auto	EPA	26*
			1257	"	CARB	26*

Model Year	HP@RPM	Torque @ RPM	CPL	Transmission	Comments	Boost Specification
’08 6.7 HPCR	350@3000	610@1600	1489	6 Manual	All Certifications	28*
		650@1600	1490	68RFE Auto	All Certifications	28*
’08 Cab/Chassis	305@2900	610@1600	8235	6 Manual	All Certifications	26*
			2886	Aisin Auto	All Certifications	26*
’09 6.7 HPCR	350@3000	610@1600	1489	6 Manual	All Certifications	28*
		650@1600	1490	68RFE Auto	All Certifications	28*
’09 3500 Cab/ Chassis	305@2900	610@1600	2780	6 Manual	All Certifications	26*
			2775	Aisin Auto	All Certifications	26*
’09 4500-5500 Cab/Chassis	305@2900	610@1600	2779	6 Manual	All Certifications	26*
			2774	Aisin Auto	All Certifications	26*
’10 6.7 HPCR	350@3000	610@1600		6 Manual	All Certifications	28*
		650@1600		68RFE Auto	All Certifications	28*
’10 3500 Cab/ Chassis	305@2900	610@1600		6 Manual	All Certifications	26*
				Aisin Auto	All Certifications	26*
’10 4500-5500 Cab/Chassis	305@2900	610@1600		6 Manual	All Certifications	26*
				Aisin Auto	All Certifications	26*

*The boost numbers for the ‘07.5 and newer 6.7 liter engine applications are approximate. There can be variance based on the amount of exhaust gas recirculation in the intake air, the intake thro the opening and variable geometry turbocharger’s position.

As a side note, did you notice how uncluttered the table was in the early years? Compliance with emissions leglislation can make things complicated.

Now that you have the specifications in hand—wait a minute, you don’t have a boost gauge? This instrument is easy to source, relatively cheap ($40-$60) and easy to install. The majority of gauges on the market are mechanical devices that do not require electricity to operate. To put a gauge in, one can use a “boost bolt” to access the pressurized intake air.



As mentioned, with a gauge installed you can use the boost readings as a diagnostic check of the engine’s performance. The engine will need to see a full throttle, loaded condition in order to make its maximum boost number. The easiest way to do this is to drive the truck up a hill. No hills in Kansas? Apply the brakes to load the engine.

How did your truck perform on the boost test we suggested? If your truck didn’t seem up-to-par there are several simple checks you can do before you take the truck to a service location. The following are some of the do-it-yourself areas to check:

- Check for quality of fuel.
- Check for full travel of the throttle lever at the fuel pump.
- Check all turbo to intercooler, intercooler to intake manifold hoses and clamps for a tight fit.
- Check the condition of your fuel filter.
- Check for fuel inlet restriction.
- Check the condition of your air filter.
- Check for exhaust leaks prior to turbocharger.
- Check for exhaust system restriction.
- For automatic trucks, check your transmission fluid level.

Hopefully our discussion on boost specifications and the use of turbo boost as a diagnostic tool will help you to ensure the best performance of your truck. Happy motoring.

Robert Patton
TDR Staff