HAVE RAM, WILL TRAVEL

Joe Donnelly's Truck and Travel Stories.

ISSUE 113: POINTS OF INTEREST

- The 1994 Field Testing article was an interesting history story (page 21).
- Tracy Martin's article mentioned the diesel/electric locomotives that have been in use for about 90 years (page 23).
- After some discussions of electric and hybrid vehicles, our editor injected some countering arguments (page 28). John Holmes noted that the power grids cannot support heavy loads from recharging electric vehicles, and commented on the limitations of Green Energy (pages 64 and 67).
- Scott Gress discussed radiator upgrades for the Ram EcoDiesel. The very limited space for a radiator in the Jeep Wrangler and Gladiator results in even less diesel capability than in the Ram (page 38).

ISSUE 112: TURBOCHARGER ACTUATOR REVISITED

James Langan's adventure with his Turbo Diesel's turbocharger actuator module addressed a topic I was already researching, but had not completed. His article appears two issues back (Issue 112, pages 82-87), but I am including it in my list of things that are of interest. His report left me with several questions:

1. Do I need to remove the right front tire? ***Editor's note: Project preparation, "remove right front tire and wheel."***
2. Should I remove the grille? ***Editor's note: "Optional."***
3. What is the best way to drain the coolant? ***Editor's note: Project preparation, open 16mm drain nut. Access is tight."***
4. Can I avoid draining the coolant by clamping shut the coolant hoses? ***Editor's note: That's how I would do it.***
5. How much of a hassle is it to let the City Diesel actuator self-calibrate each time the engine is started? ***Editor's note: "That (self-calibrating) is a huge advantage for the D-I-Y mechanic."***
6. What is the best way to access the lower actuator mounting bolts? ***Editor's note: "5mm bit turned with a box-end wrench."***
7. Is it worthwhile to drill an access hole in the shock tower? ***Likely you'll tell us in the next issue.***

Some other discussions about variable geometry turbos appeared in Issue 110 (page 34) by our editor; Issue 104 (page 22) by Jason Clifton of City Diesel; and 105 (page 46) by reader Carolina Cummins. The articles by Robert Patton and Jason Clifton are particularly informative. Robert's article is a good introduction to variable geometry turbochargers. Jason's discussions should help you to understand better the City Diesel option versus the Cummins OEM actuator used on 2007.5-2012 models and on 2013-up Turbo Diesels.

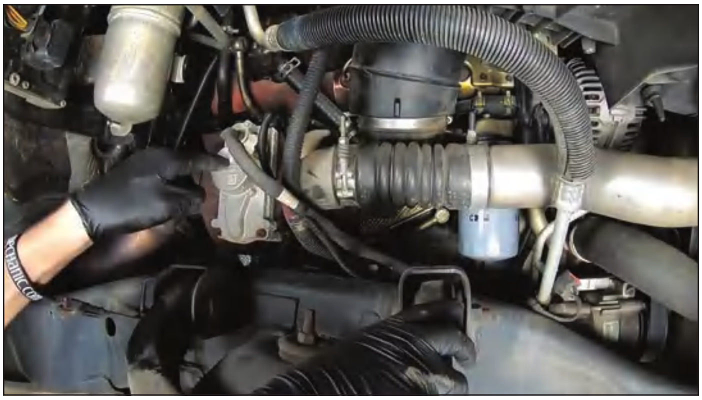
The City Diesel gearbox on the left, and the electronics and drive gear module on the right. This photo shows the halves that mate together, with the gasket and controller cable adapter below.

This photo shows the opposite sides of the City Diesel actuator. Both halves are machined from billet aluminum, not made of castings like the Cummins OEM parts.

IS THIS THE "KDP" OF THE 6.7 ENGINE? PART ONE OF MY TURBO ACTUATOR STORY

You do carry a spare tire, right? Even though you have seldom if ever had a flat tire, you carry a spare, just in case. Well, with the introduction of the 6.7-liter Cummins, we have a turbo actuator that is known to fail, eventually. When is "eventually" you ask? It seems that the lifetime of the actuator is generally between 80,000 miles and double that. How much of the time you run at high exhaust gas temperatures may be a factor, since it is mounted on the turbocharger. Otherwise, you may or may not just be lucky.

So, should you change it before that mileage range, or not? Can you realistically just carry one with you, along with the necessary tools, in your "boonie box" that otherwise has belts and hoses in it, maybe even a water pump? Can you change it at the side of the road, while the coolant temperature is over 200 degrees, in a reasonably short amount of time, and maybe even without removing the passenger side front tire? How about the plastic inner fender? (It does look like the plastic needs to come out, since you can't even see the turbo with it installed.) Are there easier ways to change the actuator? I will attempt to answer these and other questions as I change the actuator on my 2013 Turbo Diesel, in Part 2 of this article. Meanwhile, in this issue I will investigate the aftermarket actuator from City Diesel that is offered by Geno's Garage.



Stock actuator on a 2007.5 Turbo Diesel, as shown in David Pike's video.

Stock actuator on a 2013-up Turbo Diesel, as shown in David Pike's video.

Editor's note: Like Stan Gozzi's look at DEF sensors/tanks and the overall population of 2013-newer trucks (over 1 million, see pages 106-107), I took a look at total 6.7-liter engine production since 2007.5. The answer: over 1.5 million. Will there be problems? Yes.

There is an excellent YouTube video on replacing the turbo actuator on 2007.5-2012 and 2013-up Turbo Diesels by The MotorCity Mechanic (David Pike):

Cummins 6.7L Turbo Actuator Replacement - YouTube. In the video he discusses four diagnostic trouble codes (DTCs):

- U010C—lost communication with turbocharger/supercharger control module
- P0046—turbocharger boost control circuit performance
- P003A—turbocharger boost control module position exceeded learning limit
- P00AF—turbocharger boost control module performance

He goes on to replace the actuator, with detailed instructions.

Here is another guide on diagnostic trouble codes that comes from DDP Motorsports (ddpmotorsports.com). Here is their discussion on codes U010C and/or P0046:

"These codes normally point to either a turbocharger actuator or the power, ground or communication wires that go to the actuator. A bad turbocharger cannot cause these codes, but bad wiring can.

"Check to make sure your connector terminals look good and are not corroded. Make sure that you have good power and ground to the actuator (Power and ground are the two outside terminals).

"With the key "Off" (giving it plenty of time for the ECM to shutdown ~10 minutes), unplug the actuator and check ohms between the two middle pins of the connector on the harness side. It should read 115-125 ohms.

"Make sure to shake the wiring while doing both of these checks to make sure you don't have a bad wire. Also, check ohms on the two pins on the actuator itself (with the harness still unplugged). It should read between 115-125 ohms.

"*Note on the late models the wire order goes 'Ground, Can Low, Can High, and Power,' but on the early model it goes 'Power, Ground, Can High, Can Low.' The resistance check should be between 'Can High and Can Low.'"

Further from DDP Motorsports, here is their discussion on codes P003A and/or P00AF:

"The code P003 says the 'end stops' could not be found by the actuator. This is normally an actuator issue but could be caused by removing the actuator without re-calibrating it. The code P00AF can only be set by either a bad actuator or wiring fault, like was found when checking for Code P0046."

Finally, a note from DDP Motorsports on code P226C:

"This is normally a fault in the turbocharger. The code is saying that the desired vane position does not match the actual position. This is normally caused by stuck vanes or intermittently stuck vanes.

"We normally recommend people with this code get the turbocharger rebuilt regardless of what the vanes feel like. It can be caused by a bad actuator, but it is rare and if it is they will have a P00AF or P003A code set as well.

"Again, if they have all three codes set with this we do not normally encourage them to just replace the actuator. Often it can be both a bad actuator and stuck vanes."

TDR Website Correspondence

I searched the TDR forums for comments from others and responses from other members and from Jason.

Here is a helpful tip: Rather than draining all of the coolant, clamp the hoses. I am friends with a CDJR diesel technician. I told him about changing my actuator myself. He said he can do one in about 30 minutes. (It's a $2900 job at his dealership.) I asked him how because just draining the coolant takes that long. He said that after he removes the fender well, he goes above the turbo and clamps off the coolant line. He said he only loses about a cup or so.
TMyers

I will look into this option in Part Two of this article. It should be noted up front that the actuator mounting area must be very dry. There is no room for error: **You have to ensure that there is no residual coolant in the passage which might drip out onto the surface while installing the actuator. Even the smallest amount of coolant will be enough to short out the circuit board runing the actuator. You will not get a refund on the part.**
Joe Donnelly

I have a 2013 Turbo Diesel with around 130,000 miles. The check engine light came on. It was very unresponsive at first, but then the light cleared and it started running good again. The light has come on and off a couple times but it is still is running good: The code reader said: U010C.
BMeyers

This is typical of an impending actuator failure. It is time to start saving.
Jason @ City Diesel

This is the exact same thing that mine was doing (same DTC as well) before the turbo actuator failed completely. I was able to run it for about six weeks or so that way before it wouldn't work at all. Given my experience, he should start thinking about replacing his turbo actuator soon.
TimothyLong

Some further guidance was offered by Jason Clifton at City Diesel. He was asked about components in the turbo actuator.

Guys, just a couple points of clarification. Our electronics are not made in Taiwan. The board is actually made and assembled by Futaba in Huntsville, Alabama. The magnet for the motor is produced in Taiwan. (Again, the only place you can get strong enough neodymium magnets with a multi pole axial flux.) The testing, design and firmware development was done 100% in house. With the exception of cutting the teeth on the gear blanks and stamping the motor laminations all the machine work was done in house. The laminations and gear teeth were cut in the US just not in our building. All the components are assembled in house. We're as close to 100% USA-made as we could get it.

We have made some extra modifications to our actuators to address heat-related problems. The direct motor-stator to aluminum housing contact is ideal for heat sinking.
Jason @ City Diesel

Let's Talk to City Diesel

With the background information about trouble codes that point to an actuator problem and TDR website correspondence out of the way, I went back to the Issue 104 magazine and reviewed the story on City Diesel's replacement actuator. I had some additional questions (the article is 2.5 years old), so I called Jason Clifton at City Diesel. This is the follow-up story.

Q: How many City Diesel actuators are out there?

A: We have about 5000 actuators out there right now. We are currently averaging building and selling somewhere between 250 and 400 a month.

Q: Warranty: Failures versus good ones sent back?

A: Very few units get sent back, and some are due to failures. We do get a lot of calls about failures that end up being a different part of the truck. We do a pretty good job of weeding those out before the actuator gets sent back.

Q: Calibration quality on aftermarket/replacement turbos?

A: A disproportionate number of aftermarket turbos seem to not have the vane position to vane gear timing set correctly. It also seems a lot of these companies are not aware that there is a specific vane-to-vane gear timing and procedure to set it. When this is not set correctly you get a loud clicking, humming or almost an air compressor-like noise. This will kill any actuator you put on it. The problem is, if the timing is off the gear can travel far enough to lose mesh with the actuator gear. This is because the gear is only a partial gear and if its rotated far enough around you run out of teeth. We see more of the vane timing to gear position issues than we do actual calibration issues.

Q: Bench calibration versus on the truck with WiTech?

A: Bench calibration works fine, with the caveat that it must be done on the turbo that it's intended for and not removed. We see several companies selling a pre-calibrated actuator. This is an OEM actuator that they calibrate on a turbo core and then they send it to you. They then tell you where to put the vanes of your turbo before installing. There is a lot of room for error with this approach, and the vane travel on different turbos varies enough to make this approach problematic.

Q: Are smoky "tunes" sooting up the sliding vanes?

A: Smokey tunes and a lot of soot are problematic for the reason above. Beyond that, most delete tunes operate the actuator at a duty cycle they are not designed for. For instance the OEM tune has a desired airflow and a minimum and maximum vane position. This approach leads to relatively small changes in vane position. Delete tunes have this same capability, but more commonly set the minimum position to 0 and the maximum to 100. This leads to large changes in vane position and operates the actuator in a duty cycle that the OEM unit was not designed for.

More Q&A with Jason

Q: I asked Jason about remanufactured actuators. His response was lengthy.

A: I cannot in good conscience recommend a remanufactured actuator. We have seen too many cases where it tests good on the bench and fails on application. We have also seen too many cases where the failure is intermittent, and the actuator at times works and at times does not.

Then there is the "unknown" in the word remanufactured. Is it Cummins/Mopar? ***(Editor's note: The Mopar is ridiculously expensive at $1600 for up to '12, $3400 for '13 and newer.)*** Undoubtedly, they offer a higher quality part. However, the majority of the reman products we have seen are nothing more than a cleaned up and repaired core. There is not any standard. Do the chips get replaced and the circuit board x-rayed for fractures that could cause problems in a heat/vibration cycle? Highly unlikely. Instead it's power-it-up and if it communicates and moves, clean it up, put a new wire sleeve and connector on it and call it a reman. Not good.

What makes this even worse is that the circuit board and surrounding chips are only rated for so many heat cycles, and the rebuilder has no way of knowing what's been done before. Because of this kind of unknown, we would actually use a core off of a known good unit before a reman. However we really don't even like doing that unless the customer wants to get out as cheap as possible and has no intention of keeping the truck.

Given the above, in our opinion, the most reasonable option is new.

As far as specific design features that allow our actuator to last better:

The factory uses either class B or class F windings rated to 155°C, ours uses class R rated at 220°C.

The factory uses a magnet that is rated to 150°C; ours is rated to 180°C.

The factory uses a motor design that has roughly half the magnetic field strength. (This is due to a number of design choices: magnet material, magnet air gap, stator material, etc.) This means that to achieve the same torque at a stall they have to use twice as much current and generate twice as much heat.

Our motor has ABEC (Annular Bearing Engineers Committee) rated ball bearings on both sides, while the factory uses a ball bearing on one side and a steel shaft running inside the aluminum housing on the other. This is what allows us to use a smaller airgap which is the largest contributor to the stronger field.

Due to the stronger field, again, our motor has roughly twice the torque as the factory motor. However, on 2013-and-up Holset reduced this difference by using a higher gear multiplier, so the actual available torque is more like 1.4 times as much as opposed to two times.

Our printed circuit board (PCB) uses components rated to the harshest environments with the longest life in those environments that we could source. Some examples of that:

- The electrolytic capacitor we use is one intended for deep earth mining operations where heat and pressure are the most extreme. At expected temperatures and environment, it has an expected life of 20,000-40,000 hours, contrast this to the factory capacitor rated at 4000 hours.

- Our PCB substrate is made from 170c FR4 material as opposed to the much more common 130c material.

I could go on, but the long and short of it is that we designed the actuator to give you long life. We have done everything we know to do to make sure that they outlive the truck.

Q: I asked Jason to comment on trucks that might have a "deleted" aftertreatment.

A: Deleted trucks tend to see a higher duty cycle out of the actuator. My understanding is that when you are writing tuning for these trucks at a specific rpm and load you will have a desired airflow. You will also have a minimum and maximum position allowed out of the actuator that the computer can use to try to obtain that airflow.

The factory has fairly tight constraints on that position to stay emissions compliant; however, a lot of tuners like to let the computer put the actuator wherever it wants, so they enter 0% and 100% for every load position. Obviously, on a stock truck, the actuator tends to make much smaller adjustments, while on some deleted trucks they make sweeping large changes often traveling through much of the allowable range. This increases the stress on the actuator.

The '07.5-'12 Actuator

Q: Is there a difference in the '07.5-'12 actuator versus the '13-newer?

A: The earlier model actuators (2012-and-before) are a completely different design. They were designed by Delphi as opposed to Holset/Cummins. In my opinion the circuit board is a better design. They use a radial high lifetime capacitor. The connections are actually soldered. However, the motor is weaker and encapsulated in plastic. This makes getting heat out of the actuator motor area really difficult. As the turbo ages this leads to the motor not having enough torque to push the vanes aggressively enough to keep them moving. This is made worse by a different (and inferior) piston ring design on the turbine wheel. This model uses a single piston ring as opposed to the newer design with two piston rings. These piston rings are responsible for keeping exhaust out of the oil in the turbo. However, if they get enough wear, they will begin to allow some oil into the exhaust. Oil+carbon = sticky mess. The vanes begin to need a good bit of extra umpffh to move. The single piston ring design has been the standard for a long time, however the higher the back pressure the more wear on the piston ring, and these engines see a good bit of backpressure. Especially with exhaust brake usage.

The stock actuator with stock tuning does not exercise the vanes on startup or shutdown. Our actuator does the exercise at startup. On the '07-'12 trucks, soot buildup is much more of a problem. On these turbochargers I would say the actuator failure is a 60% electronic problem, 40% soot or mechanical vane problem. In general on the 2013+ trucks soot building up and vanes sticking are less of a problem than electronics failure. Just guessing, I would put the failures we see at 85% caused by electronic failure 15% by soot or mechanical vane issues.

I attribute the difference to the improved piston-ring design on the later model and the higher gear ratio allowing for more torque to be applied to the vanes. That's one reason why we went with such a large torque difference on our motor design trying to fix the torque part of the problem as best as we can.

I attribute the difference to the improved piston-ring design on the later model and the higher gear ratio allowing for more torque to be applied to the vanes.

We always tell people to make sure your vanes have full travel and move freely before replacing the actuator; however, we have had several people tell us afterwards that the vanes were stiff and our actuator "fixed" the issue. While we do not suggest this, it does seem to indicate that the lesser motor torque of the early model is a significant contributor to the problem.

The '13-Newer Actuator

Q: Okay, can you tell us about failures on the '13-and-newer turbochargers?

A: Heat is one of the two common factors in the failure of these units.

When you model electrolytic capacitor expected lifetimes, the capacitor will have an expected life hour rating. This rating is accurate if the capacitor is used at the maximum rated temperature and ripple current. As the temperature drops, the expected life goes up almost exponentially. For instance, a good rule of thumb is that for every 10°C you drop the temperature, the life of the capacitor doubles. This is because electrolytic capacitor life is related to the evaporation of the fluid inside them. The hotter they get the faster it evaporates. It does not have to be powered on to be evaporating. The failure time is fairly predictable with electrolytics. The factory actuators seem to have an expected life of around 5000 hours. Now we have not actually tested these to failure to prove this, but anecdotal evidence seems to point to somewhere around this number.

Another common failure we see in the late-model actuator is a voltage regulation failure, in other words, the voltages on the different rails begins to oscillate out of specification. This causes the microcontroller in the actuator to intermittently shutdown. This leads to brief losses of communication and a code U010c. At first, these losses of communication are quick enough that the driver does not notice any difference in driveability, but they gradually get longer and more common. Capacitance in most voltage regulation circuits is critical in the regulation and stabilization of the voltages. Fixing this problem is much more difficult because the factory chose to use an axial capacitor as opposed to a radial. The problem is there are far fewer options for sourcing high-temperature/high-life capacitors in an axial footprint. Maybe the factory has the resources and capital to fix it, but when we were researching for ways to extend the life of these actuators we could not find a suitable capacitor to significantly extend the life.

A third common cause of failure is that instead of soldering some of the through-hole connections (i.e. the motor windings to the board and the external connector to the board), the factory chose to use pins with a spring-like retention and tight fit and just slip them in. When you build a printed circuit board, the holes and vias that have copper all the way through them are typically coated with a conductive coating after manufacturing and a really thin layer of plating. Without that thin layer of coating on the inside diameter of the hole, the hole or via will not conduct and connect all the layers of copper in the board.

Conclusion

In this article I've tried to build on the foundation of the previous write-up in TDR 112. I had the opportunity to give you background information from DDP Motorsports and I provided you a link to a solid YouTube video that David Pike has produced. I recapped some of the discussions from the TDR's website and I had the good fortune to interview City Diesel's Jason Clifton and do a lengthy Q&A with him. Next issue: the step-by-step installation of the turbocharger actuator.

Joe Donnelly
TDR Writer

RECENT ADVICE ON THE 68RFE TRANSMISSION FROM TRANSENGINEER

Question: Are OEM or metal accumulator pistons better?

In my opinion, there is no need to replace the plastic accumulator pistons with metal ones. We originally used metal (aluminum) accumulator pistons, and I saw more problems with those than with the plastic ones.

If you do replace the pistons, I don't think you'd need to do a relearn, unless the new pistons have a different overall length (and therefore, different travel distance) than the originals.
TransEngineer

Question: What valve body components are weak?

The accumulator cover and its mounting screws pose a common point of failure. I would think using an improved aftermarket part there would be a good idea. But the pistons themselves are not the problem. The pistons are okay as is.
TransEngineer

Condition: Engine rpm flare

If you have engine "flare" during shifts, the first thing I would suspect is a change in torque converter clutch (TCC) state, not actual clutch slippage. Do you have a scan tool that will display TCC state? Sometimes the shift sequence is:

- Unlock TCC (change from full lock to partial lock, so engine speed increases)
- Make the upshift
- About one second after the shift completes, relock the TCC

So I would see if the "flare" you're noticing is actually just a change in the TCC state.
TransEngineer

Condition: After warm-up, a hard shift into 1-2 then into 4th

Am I correct in assuming that you're getting a P0871 fault code? If so, then yes, the likely culprit is a worn solenoid switch valve (SSV) bore in the main valve body, so a new valve body assembly is in order. A new solenoid module would not be needed, although Mopar valve body assemblies do come with new solenoid modules included.
TransEngineer

Condition: Pulling a trailer, around 40-50mph, I get a hard shift and code P0871 is present

Do the valve body (VB) swap and see if that takes care of it. If the P0871 repeats after replacing the VB, then it's likely a wiring issue.
TransEngineer

Condition: Limp mode and codes P0933, P0721

I would suspect problems with the output speed sensor wiring (for P0721) and the line pressure sensor wiring (for P0933).
TransEngineer

Condition: When loaded with my trailer, it flashed P2048 and U0402.

U0402 means implausible or invalid data was received from the transmission control module (TCM). The most likely cause would be a bad wiring connection somewhere between the TCM and ECM. So for starters, I would disconnect the wiring harnesses at the TCM and ECM and inspect them for corrosion, bent pins, terminals pushed partway out (not flush with the other terminals), etc.

On Aisin trucks, one other common trouble spot is a wiring connector that is right behind the splash shield of the driver's side front wheel. So you might check that one also.
TransEngineer

Condition: P0868 after long drive, no symptoms

This sounds like the problem happens when the transmission is unusually warm (after long drive, at altitude). So, I'm guessing you've been running a lot of uphill grades which will bring the temperature up. This probably means you have some wear in the pump and/or valve body, which gives you some leakage of line pressure. This will naturally get worse when the transmission is hot and the fluid is thinner. But yeah, if it only happens like once a month, at altitude, then the dealer won't be able to duplicate it and they likely won't be able to address it. I would just continue to monitor it until it becomes more prevalent. The good news is that it's not bad enough to cause slippage in the transmission, and it's not bad enough to be a problem at normal operating temperature.
TransEngineer

Condition: P0934 on morning start-up occasionally

If you're getting code P0934, that is a sensor and/or wiring problem, not actually low line pressure.
TransEngineer

Joe Donnelly
TDR Writer