Exhaust Gas Temperature Basics - Diesel Tech

EGT Basics You Need To Know

Diesel Power, July 01, 2006

Second to oil pressure, exhaust gas temperature (EGT) may be the most critical operating parameter on your diesel engine, because excessive EGT can bring a host of problems that fall under the meltdown category, both figuratively and literally. Every material has a melting point, some lower than others, and when things get too hot, expensive parts within or attached to your engine start welding themselves together or disintegrating into the exhaust pipe.

Many people know that excessive EGT is not a good thing, but there's an equal amount slightly confused by all the numbers being tossed about, concerning what actually constitutes high EGT and where to put the EGT gauge probe, since their exhaust brake or big downpipe has a fitting but the manifold doesn't. We'll give you a few clues here, with the caveat that every engine is different, and, like EPA mileage estimates, your EGT will vary. Also, note that like any temperature, EGT can be measured on many scales, so for the sake of consistency, every temperature value mentioned in this article is given in degrees Fahrenheit.

One element in the confusion is an apparent lack of standard in measuring and setting EGT limits. While one engine manufacturer might say the EGT maximum is measured no more than 6 inches from the cylinder head, between cylinders No. 3 and 4, in the center of the pipe, another builder will use a different formula. The good news is that most engineering bases EGT on the "turbine inlet temperature," meaning in the exhaust stream just before it enters the turbocharger.

You could measure EGT at each exhaust port as many engine developers do, but since that gas flow is an individual pulse, the average is not as high as it is at turbine in. Furthermore, you need a rather expensive thermocouple and data acquisition to measure such rapid fluctuations with accuracy.

With enough perseverance, you can often find a maximum EGT for either turbine in or turbine out; the latter is often the results of measuring the same engine at two points, simultaneously. However, the delta cannot be considered a constant among different engines or states of tune on the same engine.

Another element involves conditions in which maximum EGT is measured. Obviously, engine dynos and test stands are quite consistent, but if you're dragging that overweight toybox up a 7 percent grade with the A/C on because it's 110 degrees outside, your engine might reach maximum EGT faster than during the builders' tests, and it may not drop as much between turbine in and turbine out because of underhood airflow.

Increasingly, common variable geometry turbochargers also deliver different deltas across the turbocharger because as the vanes move, temperature and pressure in the exhaust changes. At maximum load WOT and high boost, the variance between turbine in and turbine out tends to parallel a conventional turbo, but part-throttle mid-rpm loads may not.

If you remember high school chemistry, that pot of pasta you boiled last night, or the last time you accidentally leaned on your air compressor, you'll recall that temperature increases with pressure. In fact, this is the principle that drives your diesel engine by using compression to generate enough heat to start the combustion process.

As the exhaust gases come out of your engine and across the turbocharger, the heat energy and pressure in them are used to drive the compressor wheel, thereby dissipating some heat energy in the exhaust gases. As a result, peak EGT typically drops 300-400 degrees between turbine in (TI) and turbine out (TO).

Stress the word peak in the above generalization because without some boost pressure, little heat energy will be expended as exhaust gases cross the turbine. At idle, the turbocharger is doing virtually no work, and the measurable difference in EGT ahead or behind it won't be nearly as significant. One must also remember that turbocharger pressure ratios (pressure into compressor to pressure out of compressor) do not always correlate with boost levels.

To better find out how the numbers usually play out, we checked with Banks Engineering, Edge Products, and TTS Power Systems. We also fitted out a test mule with a dual-reading Westach pyrometer and identical probes, with one thermocouple at the collector in the manifold about 1 inch ahead of the turbocharger housing and the other in the exhaust brake about 1 inch behind the turbine wheel.

The mule is an early Dodge pickup with the Cummins 5.9 12-valve and Bosch rotary injection pump. Even with a smaller wastegated housing, larger intercooler, and "adjusted" pump, this engine doesn't make the power levels of modern trucks: It was last chassis dyno'd at 228 hp at 2,400 rpm and 643 lb-ft at 1,350. However, with a fully mechanical injection system, the right foot has direct control of fuel load (no electronic control of a wastegate or VGT), and with a manual gearbox we could smoke it at will. Smoke equals incompletely burned fuel and higher EGT, so characteristics were easy to note without dragging that toybox out of town.

The indications in our test mule were right in line with predictions; the numbers are approximate because of gauge scales and condition transients. Although we didn't quite reach this engine's design maximum, we got up to 1,200 turbine in and 875 turbine out, and at full throttle and heavy boost, the delta (difference) stayed in the 300-350 degree range across the 1,200 rpm band where that boost is available. In cruising conditions with 5-7 psi boost, the average drop across the turbo was 100-150 degrees, and at idle, the difference was less than a needle width on the gauge. With the exhaust brake on and backpressure between 30 and 40 psi, the turbine inlet and outlet were nearly identical as you might expect. Check the accompanying graphs for more examples of various conditions.

A survey of engine builders found some limits, all measured as turbine inlet temperature, for '06 model-year pickups; 2007 information is still being finalized as fuels change and engine sizes grow. All three pickup diesels are available in other duty cycles, applications, and ratings, and because of changes to materials, hardware, such as pistons, valves and seats, manifolds, turbos, and so on, and software, may have different EGT limits in those applications. Note that these are guidelines since many variables contribute to engine longevity.

The Duramax 6.6L in GM pickups (the Kodiak/Top Kick and G-Van use a different rating) has a limit of 1,365 continuous, with 1,435 allowed for transients of five minutes or less.

Ford labeled EGT as developmental information it doesn't disclose, a view echoed by the Power Stroke builder, International. In fact, International doesn't use the term much with the advent of variable geometry turbos but would allow that from a design standpoint it would typically assume maximum EGT (at turbine in) under full load would be around 1,200 at sea level, higher at altitude. International also reminded us that there are many factors that go into reliability and durability, and giving a blanket EGT value would be irresponsible. Combined with what we picked up from the aftermarket, a stock 6.0L Power Stroke functioning normally probably won't indicate greater than 1,200, and most aftermarket tuners try to keep the limit to 1,250.

We could not get a maximum EGT value or similar from Cummins Engine either. Based on production engine indications and aftermarket experience-read wreckage-it appears that 1,350 is a safe number for P7100-and-later engines. As with all engines, if you get baseline data before modification you'll have a good idea what can be considered long-term safe.

Since fuel input contributes to heat, you can use a pyrometer for economy indication-cruising at 500-600, instead of 700-800, will probably improve your fuel economy. Exhaust smoke indicates unburned fuel and means high EGT, but most dashboard pyrometer thermocouples don't pick up spikes when you blip the throttle and make a puff of smoke, and that momentary high EGT won't hurt the engine.

Which probe mounting point do you use? Either is valid for a stock engine, though the preference, particularly for a modified engine, is turbine in. The majority of engineers all go with turbine-in temperatures-the turbo is much easier to damage than an exhaust pipe-and it takes any pressure drop variable out of the equation. In fact, some of the performance shops we spoke with don't even measure turbine out anymore because turbine in is always the higher, quicker indicator during development and electronics that de-fuel based on EGT readings should get the feed from turbine in.

Some consumers worry about the thermocouple probe breaking off and wrecking the turbo, but this is extremely rare; we've not heard of such an event for decades. Besides, if it got so hot that the thermocouple went soft or fatigued, there was likely a catastrophic event preceding it that did in the works prior. Wherever you put the probe, make EGT the last gauge you view before shutdown, so you don't bake the oil in the lube passages and seal the turbo's fate.

It is possible anything can break. But, if you follow diesel racing and saw the Cummins tractor engine that broke at 100 psi boost, you know it wasn't a head gasket, turbo, or thermocouple that gave up-it was the engine block!

Power Stroke EGTThis data is from an '03 6.0L Power Stroke under partial load conditions. Note that at lower throttle settings, less heat is generated and the drop across the turbo is lower. A "heat soak" anomaly is shown in the last line as the truck has finished a long pull (note speed) and the throttle is closed, so the turbine-in temp dropped faster than turbine out because of all the heat stored in the turbine and its cast-iron housing.

RPM	Turbine-In Temp	Turbine-Out Temp	Delta	TPS	MPH
3,900	950	720	230	22%	55.7
3,800	1,060	790	270	57%	53.0
2,500	1,030	760	270	60%	53.8
2,500	660	540	120	0%	44.4
2,400	980	750	230	55%	52.4
1,700	1,040	800	240	48%	54.1
650 (Idle)	690	705	-15	0%	65.8

Duramax EGTA stock '05 Duramax LLY was tested under full load conditions, all at wide-open throttle. As engine speeds rise and inlet temperature comes down, turbine-out temperature drops even faster, suggesting perhaps that fueling is increasing while boost remains constant-it's impossible to tell without more data.

RPM	Turbine-In Temp	Turbine-Out Temp	Delta
3,200	1,235	810	425
3,000	1,255	865	390
2,800	1,270	900	370
2,600	1,280	925	355
2,400	1,270	935	335

SOURCES

Banks Engineering
Turbocharger
Edge Products

Geno's Garage (Westach)

TTS Power Systems
www.ttspowersystems.com

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