Interesting things to investigate over the winter: boost control. PART 2

Calibrated Success
EFI Training - Tuning - Consulting

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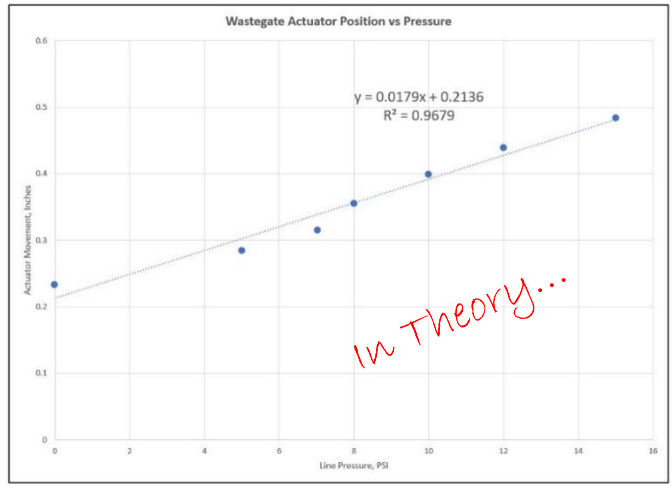
In Part One, we examined the dilemma of low boost and power in our 2009 LS3 Corvette with an APS turbo kit. In Part Two here, we'll head to the dyno and see the results from what we learned.

The setup includes a pair of Garrett "GT3076r" turbos that made a solid 600/600 to the tires on the stock LS3 engine over a decade ago. We also have a SirchLabs Cortex electronic boost controller that ties into the e38 ECU to grab RPM and vehicle speed so that it can do boost by gear. Ours is programmed with a target of 10psi in 4th gear, provided the engine hardware can deliver. After swapping to ported heads and a mild 220/218 cam, we expected a healthy bump in power. What we exposed was a mismatched combination that struggled to perform. The turbos that were a good match to a bone stock LS2 just were not in their happy place on our LS3.

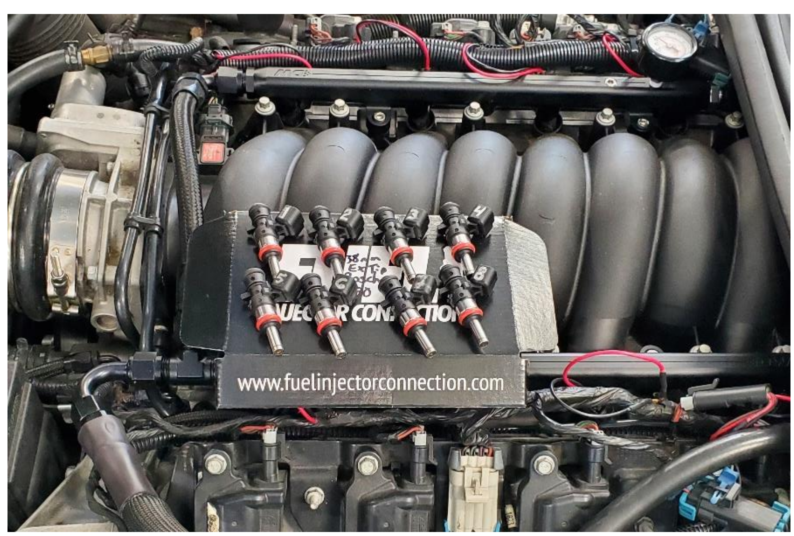
The added flow brings with it added exhaust backpressure. Remember, we still have cats and the Z06 dual path mufflers on this this car. This increased backpressure has a tendency to push our wastegate valve open too early, so the initial solution became clear after taking a few measurements in the shop. Based on our measured actuator displacement vs diaphragm pressure, it was decided that two turns should theoretically get us up to a more reasonable intake pressure and hopefully restore some power. As we'll soon see, the real world includes other effects that must be accounted for if we want the right result. The combination of exhaust backpressure acting on the wastegate puck along with the actuator diaphragm meant that we needed more preload to hold the right position at high RPM. A lot more.



At the end of Part One, the math pointed us to adding two complete turns to the wastegate rod preload. To hit our desired boost level. After the Michigan roads warmed up enough to drive and check, it became obvious that we needed a little more. Back in the shop and under the car, we put a third turn into the wastegate rods along with a noticeable increase in tension as we stretched them over the pins on the swing arm. Back on the road, things started happening fast in second gear. That's good, but not wanting to get arrested, it was time to head to the dyno.

But before heading straight to the dyno, I did a little extra planning. I want to make the most of my dyno session, so I drained some of my full tanks of pump gas (currently measuring 11% on the flex sensor) to leave room for an on-dyno fuel change. I wanted to see not only if the engine was happy on pump gas, but also on a strong blend of ethanol. A little MacGyver action in the shop, and I was able to use a spare length of -8AN line and the HPTuners scan tool commands to trigger the fuel pump and remove some of the extra fuel before I headed out. I had a couple cans of E85 waiting for me at the dyno.

If everything actually worked, and I somehow managed to make 11psi all the way to redline on a tank of high concentration E85, the existing Deka 60 injectors were not going to be enough to keep the engine fueled. The good news is that there are a ton of good solutions for this available today. I got a set of the brand new Bosch Motorsport "1050" injectors from Fuel Injector Connection as some insurance here. This new design is completely ethanol tolerant, so no more worries about corrosion over time if you don't pickle them with gasoline for storage. Their extended tips protrude slightly into the port, but this is not an issue with airflow when we have such large ports and boost available. After a quick trip to my Calibrated Success Fuel Injector Test Bench, I had the precise calibration data for this exact set of injectors available to drop right into the tune. It's always nice when the engine fires right up on the first try without any drama after such a large change because we got the calibration data right. I may have issues on the dyno, but running out of fuel won't be one of them.

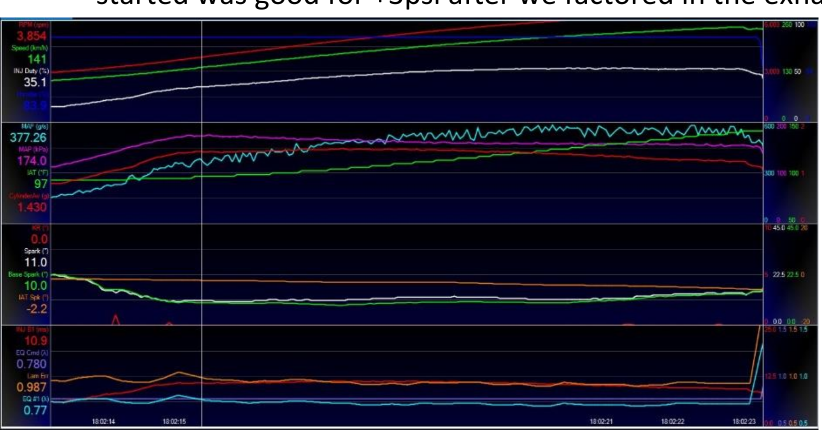


With the car strapped to the dyno, it was now safe to wring it out a little and see exactly what our boost curve looked like on a datalog. If we make it to higher boost levels, we'd also get a chance to see what the spark tolerance was for our new hardware combination under higher loads. On a flex fuel enabled vehicle, it's important to make sure your base calibration on pump fuel is safe before adding octane with the ethanol. You don't want to get in a position where you can only fill up with gasoline and have to worry about knock at WOT, so dialing in the spark tables on pump gas should be done completely before adding ethanol and adjusting those separate spark adder tables.

The first pull on the dyno is always telling. All of a sudden, the guesswork and theory stops and the hard data arrives. Between the dyno measurements and the ECU datalog, we now have a clear picture of what's happening under high load.

Whoa, we have a little cleanup to do here. It looks like tightening the wastegates did indeed raise our boost and cylinder load. We now made it up to 9psi at 3500rpm, but that dropped to about 7psi up top. It also exposed the need to clean up our base high octane spark table a bit to remove the knock, especially from 4600-5600rpm. No big deal, at least it happened here where we can see it and fix it. Peak power on this dyno landed at just 544rwhp, but that's just a reference measurement for today. This particular dyno has a reputation as a heartbreaker compared to others around town, so I won't fret about the "low number". Previously, we made low-500's rear wheel with the lower boost on this dyno. Our focus for now is any change we will see from adjustments in today's session.

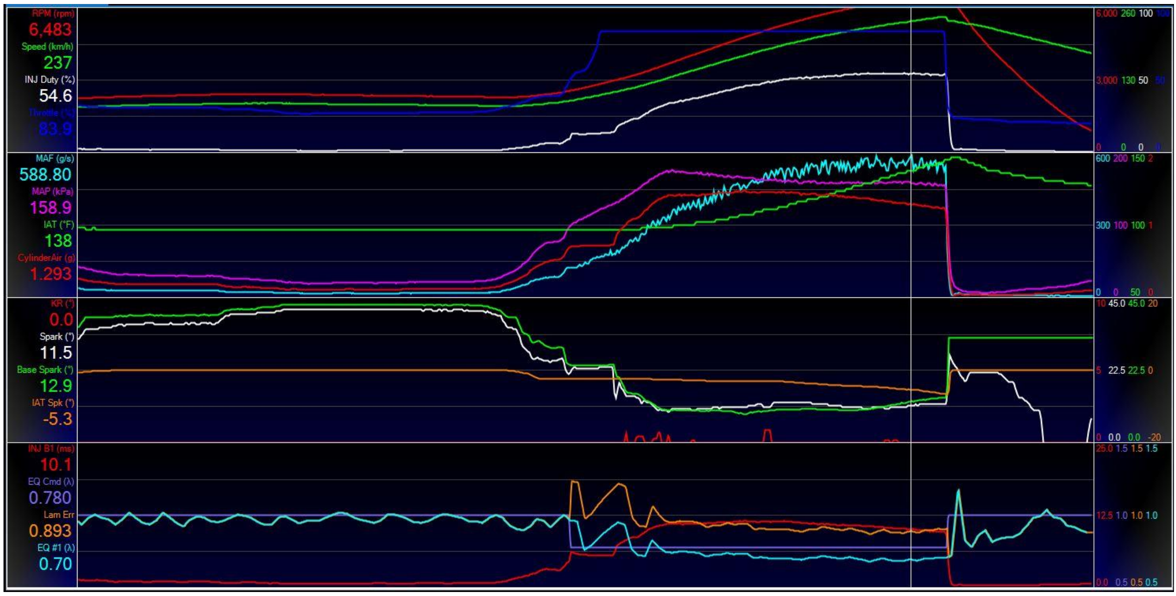
Cleaning up the spark to avoid knock did not add any significant peak power and fueling was pretty much on target. The only knob left to turn for power was more boost. It appears that being +3 turns from where we started was good for +3psi after we factored in the exhaust backpressure effect on the gate pucks. This is only ***HALF*** of the 2psi/thread we expected from our earlier shop measurements, so the backpressure effect is not to be ignored in this case. We crawled under the car on the dyno and put another complete turn into them.



The added preload got us to an initial 10psi at 3500rpm and only dropped to about 8psi up top, another 1psi across the board as seen earlier. The Boost controller just can't do any more to help us without some help from spring pressure to resist the backpressure on the pucks. Looking at a log from the boost controller, we can see zero input down at 3500rpm where we easily hit the 10psi target and the duty cycle walking up to 80% at redline as it tries to bleed boost signal to the diaphragms to hold manifold pressure at 10psi. Even almost wide open, we only get 8psi, which means the boost controller itself can’t win with our production single port wastegates and springs.

Unless we tighten the gates even further (risking overboost at 3500rpm), we will have to live with 8psi up top. With the calibration cleaned up, this new boost level was good for 607rwhp, an increase of 63rwhp from our baseline. The difference between the two runs is typical of a good dyno tuning session on a boosted car.

With our boost level now set as good as we’re going to get it today and our tune confirmed as safe with only 11% ethanol, it’s time to raise the average. We added 10 gallons of pump sourced E85 to the tank and saw our reported concentration jump to about 57% ethanol on the scanner. While not all the way at the top of the scale, we recognize that once we get to about 60-65% ethanol concentration, there is almost no real benefit to be found in octane or cooling effect from going higher. Our flex fuel equipped ECU automatically adjusts the commanded fueling for the new stoichiometric balance point reported by the sensor. We began with a modest adder in the flex fuel spark table of +3° up top. We later bumped that to +5° after watching for knock on the logger. Interestingly, this +5° of spark tolerance from the ethanol almost exactly counteracts the -5° of spark retard required for the 140°F boosted inlet temperature on the dyno. For the given conditions on the dyno today, this is all she's got. The good news is that out on the road, the large twin front mounted intercoolers usually keep inlet temps significantly cooler when moving. The dyno lab is a worst case scenario with limited airflow. If it lives here, it'll be just fine out in the wild while making



slightly more power with cooler inlet temps. The dyno reported just shy of 650rwhp with the ethanol blend in our final run, which correlates with our airflow numbers indicating north of 700hp at the flywheel.

So, what did we learn?

Overall, we still have a great driver. The engine is properly calibrated for fueling, spark, and throttle. It's surprisingly easy to drive in traffic for a ~700hp car. With catalytic convertors and all other emissions hardware in place, it's also pretty responsible. Other key takeaways include:

1. Carefully matching your hardware can make life easier or harder. In our case, the turbos were a great match to the stock engine, but we would really want something different with the new combo if we had a choice.
2. Brute force and ignorance can sometimes move the needle a bit. By adding more wastegate preload, we were able to force the turbos to deliver more boost despite the increased exhaust backpressure and struggling turbines. Tightening existing wastegates is free, upgrading both turbos would have been well over $5,000.
3. Ethanol once again proves to be a worthwhile upgrade on boosted engines. By taking advantage of the higher knock limit and cooling, we saw ~40rwhp going to a 57% blend from 93 octane pump gas at the same boost level.
4. Adding more power will not likely make this car much faster on the street. It has enough power to incinerate the 335mm tires through the first three gears. Since I'm not willing to sacrifice cornering or comfort for better straight line traction, I'll live with it.

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