Interesting things to investigate over the winter: boost control.

Calibrated Success
EFI Training - Tuning - Consulting

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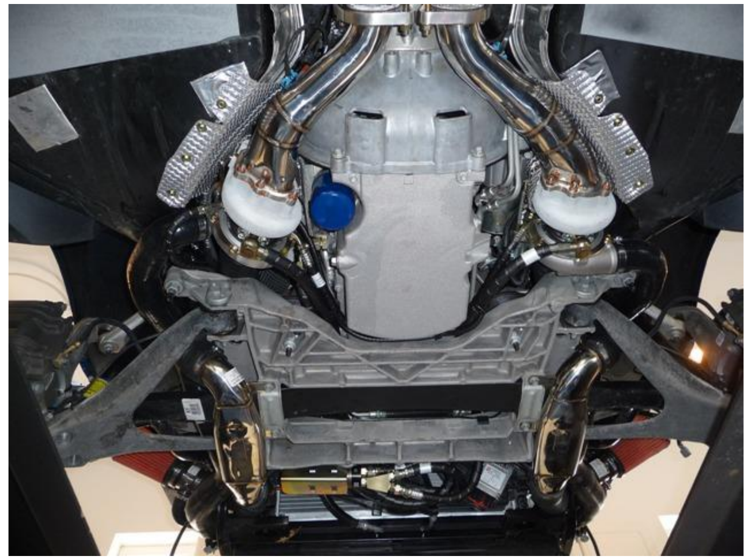
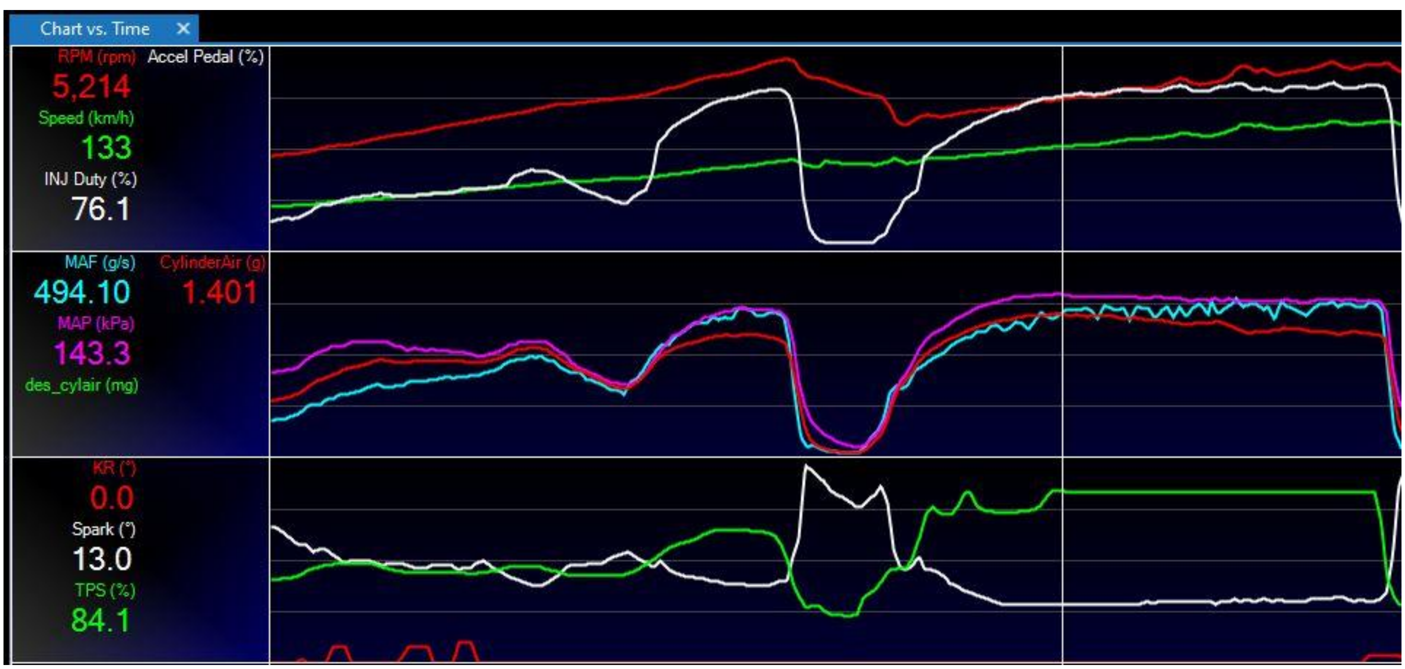


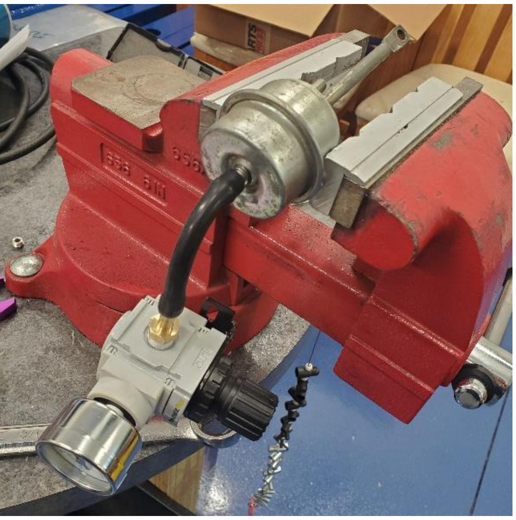
One of our demo vehicles here is a 2009 LS3 Corvette with an APS turbo kit. The setup includes a pair of Garrett "GT3076r" turbos that made a solid 600/600 to the tires on the stock LS3 engine. For years, we used lessons from this vehicle to demonstrate proper ECU calibration using the factory GM e38 control strategy, even in boost. The vehicle still has a full complement of emissions equipment, including catalytic convertors.

After completing a swap to ported cylinder heads and a very modest camshaft upgrade, I noticed that the twin turbo LS3 felt a little "softer than expected" up top. I checked all the usual suspects. No loose hoses, AFR was good (even on various blends of ethanol), spark was appropriate with no knock, IAT was good. It just wasn't holding the same boost level as the car did prior to the head/cam swap. MAF numbers and "butt-dyno" agree at around 580whp when I was expecting more like 650-700 if it were to hold 7+psi all the way to redline.



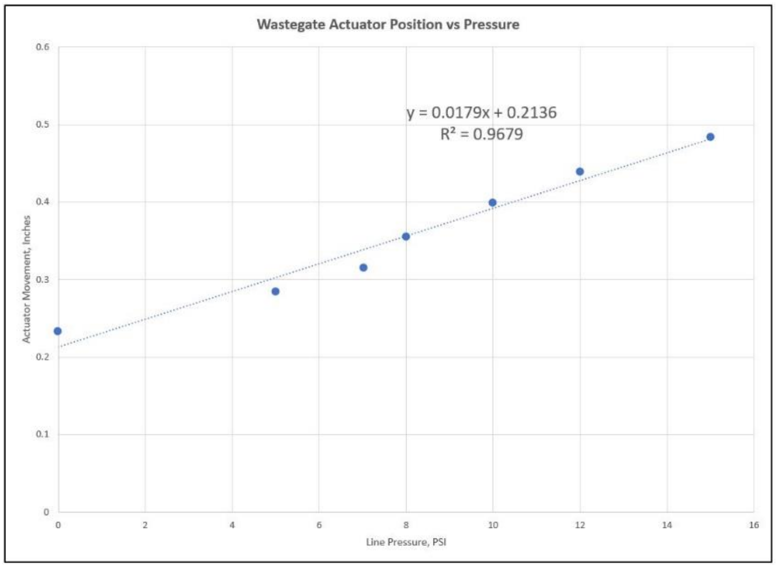
I went so far previously as to pull the turbos, have them inspected and reset the wastegates off the car at the recommended "1/2 hole" preload. Still, it bled boost with RPM. Almost certainly, the 56.5mm turbine wheels (I measured them myself) are a bit small for this engine. The Garrett turbine maps tell us to expect significant backpressure at these flow levels. Making things worse, if we are not able to maintain a reasonable boost level, we risk falling off the bottom right of [the compressor map](#) as well. Losing efficiency here means that the turbine must work even harder in an attempt to create shaft work and compressor flow. Consulting multiple turbo experts, I got multiple opinions, most centered around "you are probably out of turbo, you need something bigger to flow that much exhaust and keep it in the efficiency island on the compressor."

While they may be right, spending another $5-8k seems a bit rash when I know that others have made a lot more power than this with the same turbos/kit on a C6. Others have posted dyno sheets showing 700-800whp using the same turbo kit, also on modified engines. They were successfully running 10-12psi with the same turbos. Something else has to be happening.



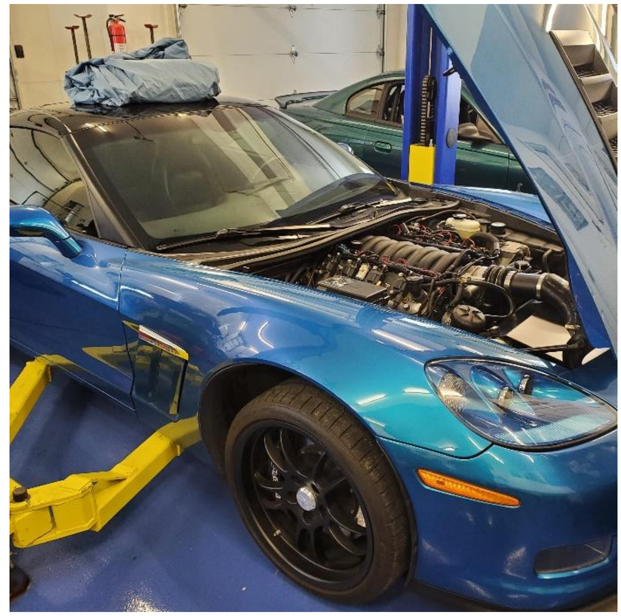
So while updating the fuel system in the tech center, I pulled the wastegate actuators and set them in vise and applied pressure with a 0-20psi regulator on the shop air line. I could then measure the actuator rod movement as I slowly increased supply pressure to see the relationship. The first important realization is that these actuators don't just pop completely open at a single pressure. Instead, they creep from one position to others as a function of pressure. This explains why the same Garrett actuator part number (445963-7) is advertised as both a "7psi" and a "12psi" actuator. They're fairly linear if you can look past my rough eyeball measurements and error.

You can also see that the rod begins to move with as little as 5psi on the diaphragm when there is no preload. When installed, they have some preload, which effectively shifts the linear offset of the graph, but this also does not take into account any exhaust backpressure acting upon the wastegate puck as RPM and flow increase. THIS is what was most likely causing the gates to open prematurely and bleed boost below what would normally be the static wastegate pressure. At this point, a boost controller will not help on a single port wastegate because it's the backpressure on the puck pushing things open, not necessarily the diaphragm pressure on the top. We need more force to resist the backpressure.



MS Excel to the rescue. Let's math it! Recognizing that there is a linear relationship, we can next solve for how much movement we get per psi applied (the slope of the line in inches/psi) 0.0179"/psi. Next, we get its inverse (psi/inch of movement) at roughly 56psi/inch. We know that the actuator rods are ¼-28UNF. That means there are 28 threads/inch and each thread is 0.0357". Applying the slopes above tells us that we should expect a change of roughly 2psi/thread. That's pretty handy, as it now tells us how much change in boost pressure to expect per turn of the rod in preload. Adding two complete turns would preload the spring by enough that it would take *an additional 4psi* to open the gates. This is, of course, ***IF*** there was no additional influence of exhaust backpressure on the pucks. Since we know that the relatively small turbines are creating enough backpressure to force the gates open early on the lower boost level, we don't expect this to get much better as we increase boost/flow.

If the math works, we would expect to see delivered boost go from about 5psi up top to something closer to 9psi. Realistically, I'm *guessing* there's another ~1psi lost due to exhaust backpressure and puck opening. But even that would result in radically improved performance on the street. 8-9psi on top of a healthy breathing LS3 with ethanol is more than most street tires can plant.



Once the snow melts here, we can take the car out and re-test to see exactly what the effects really are. For that testing, we're also going to throw an exhaust pressure sensor in one of the manifolds upstream of the turbine to record that as well. We might be surprised by the number, but it's just data. Useful data can help us make a plan to improve before we commit to throwing money at a problem that may just need a few turns of a wrench instead.

One of two things is likely to happen here. Either:

1) The added preload is enough to hold the wastegate pucks shut against a little more exhaust backpressure and we harness enough turbine work to spin the compressors to our desired boost level. Or…
2) Exhaust backpressure is strong enough to overwhelm the pucks even with the added preload and we drop below "gate pressure" again.

If #2 happens (pun intended), we could try tightening the gates even further, at the risk of over-boosting the engine in the midrange before exhaust pressure helps force the gates open. If this happens, we could potentially apply more gate pressure by changing the boost reference from the intake manifold (MAP) to the compressor housing, which should see a few PSI higher due to the natural losses in the system.

If we still overshoot on delivered boost there, we need to look at different actuators. This may be a real challenge because package space does not allow for larger diaphragms/housings. Let's hope we have a way to hold pressure all the way to redline and keep that pressure below ~11psi to make sure the stock LS3 bottom end remains pump gasoline friendly.

As they say, "stay tuned", and we'll have more information when we get back out of the shop with the car.

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