Turbo Dynamics Z1 reflash/ ECU tuning

Ben Paquin and his partners of Turbo Dynamics in Quebec, Canada (www.turbodynamics.ca) have been reprogramming turbocharged street cars' ECUs for max power on pump gas for several years. Last year they figured out how to reprogram the Arctic Cat Z1 ECU. Ben told me they spent much of last winter testing various states of tune, mostly on pump gas at local dyno tuning facilities and in the field. Ben has created what he feels are optimal fuel and timing curves to allow max knock-free power on various octane fuels. Turbo Dynamics settled in on a four-position switch (a concept similar to that used by Speedwerx and JD Powersports with their own ECU reprogramming) to allow access to up to four of a variety of different "tunes" they have created for various grades of gasoline. The customer sends his ECU to Turbo Dynamics (or to one of the US distributors), and the ECU is reprogrammed with four different boost/ fuel/ spark maps.

Turbo Dynamics also has integrated a bright red warning light into their system to let Z1 owners know when even light detonation is occurring. As we would see during our dyno test session, temporary severe knock from substandard gas can occur with no factory warning light or code! Staying at WOT while even light knock is occurring can be hard on parts (see the many explanations of detonation in the archives on this website by Kevin Cameron The Cellar Dwellar). The Turbo Dynamics deto light can warn you, well in advance of even minor damage, that your octane is insufficient for the time on boost/ boost level/ time on boost/ engine temperatures.

There are other Z1 ECU options available including a "stutter" feature and anti-lag that we did not test here.

The Z1 that Ben brought to test/ tune was a stock demo unit borrowed from his Cat dealer, fitted with a larger capacity fan cooled intercooler/ aluminum larger diameter charge tube kit that Turbo Dynamics sells as an upgrade. This is a bar and plate unit, with end tanks designed to withstand 50+ psi boost levels with aircraft quality TIG welds. All test data is shown with the large intercooler. On the dyno, with close to 80mph outside air blasting the intercooler at point blank range from a 10" diameter duct, big intercoolers sometimes fail to show a significant increase in power over smaller stock intercoolers (as we experienced during the Polaris FST test earlier). We had no stock intercooler to compare, so we can't be positive what dyno benefit the large intercooler provided. But in the field, with hood partially blocking the intercooler there is likely an airflow/ power benefit from just the larger heat sink of a big intercooler during intermittent operation on boost. In addition there is added cooling airflow at moderate vehicle speed through the core from the built-on fan unit.

Turbo Dynamics also sells a digital, fairly complex water/ methanol injection system that was fitted to our dyno mule Z1. I consider water/ methanol injection invaluable to anyone wanting to make best power on pump gas. I bought a used Whipple screw supercharger kit from my pal Rusty Rovere and installed it on my Chevy Avalanche 5.3 V8 engine. But since the 5.3 V8 is on the edge of deto bone stock, adding 5-6psi of non-intercooled

boost was nearly futile since even on 93 octane the ECU sensed light knock and always yanked the timing back to nothing resulting in limited power gains. But after I installed a water/ methanol injection system (using 20% methanol windshield washer fluid from the truck's reservoir) now the ECU pulls no timing and I get a significant power increase over stock, even on 87 octane! As I recall, the evaporating blue juice has reduced the compressed charge temp on my 5.3 at least 100 degrees F! I use one gallon of windshield washer fluid for each 25 gallons of gas—a cheap way to make good boosted power on pump gas. On a sled like the Z1, custom blending cheap methanol with water is another way of tuning/ adding extra fuel as required if one needs it (some car tuners I know go as high as 100% methanol to supplement tapped-out stock fuel systems, but a 50/50 mix is said by Ricardo to be the most beneficial for just suppressing deto).

Turbo Dynamics' test session

Ben planned to come to DTR and demonstrate his various tunes on his dealer's stock Z1. He also wanted to test a new quiet muffler that D&D was making for him (he calls it a "D&D TD quiet muffler"). He also had a Bikeman straight through glasspack muffler and a Bikeman welded sheetmetal turbine outlet that separates wastegate flow from turbine outlet flow. Most of the testing was done with the stock cast iron turbine outlet and the D&D TD quiet muffler (the higher flowing BMP turbine outlet was tried late in the session). Ben figured on perhaps a day of testing, but when he observed the plethora of new data provided by the SF902 system (compressor inlet/ outlet/ intercooler outlet temps and pressures, exhaust turbine inlet temp and pressure, gross and net fuel flow from pump and bypass, airflow CFM etc) he decided that even a few new tweaks to tuning and their effect on temperature, pressures and power would be very useful to him and his company. Plus with Ben Paquin being as HP-greedy as anyone I know, creating maximum power on pump gas would be on the agenda as well. One day turned into two days, but Ben learned way more here in two days than he could have expected, to enable him to deliver the best possible pump gas power to his customers.

Our test session began with engine knock, because the fuel in the Z1's gas tank was from last winter and of questionable heritage. The first dyno test with 12 psi boost created severe detonation, causing power to drop to below stock in the midrange. Ben showed me on his AC EFI monitor that the ECU had pulled nine degrees of timing to get rid of the knock!

So to experiment, instead of going to buy new gasoline right away, Ben energized the water/ methanol injection and the knock disappeared immediately, and the timing commanded by the Turbo Dynamics 91 octane program stayed constant along with HP. That was a great demonstration of the cooling properties of vaporizing water and methanol. But we drained the bad gas, and bought 93 octane w/ 10% ethanol gas for the rest of the test session.

Ben swapped pipes/ mufflers/ turbine housings around, and jockeyed HP around with the four-position map switch as well as some fuel/ timing tweaks for more power. Here is a listing of meaningful combinations, with basic dyno data. Note that most tests begin

close to peak HP, like we did with the Polaris FST. We allowed very little time testing at the usual slow 250 RPM/ second acceleration rate in the midrange where torque is highest (and more likely to knock), since in the field you accelerate from clutch engagement to peak HP RPM in a second. In retrospect, we could have done more with the stock quiet, but very restrictive muffler to see how much knock-free HP we could have achieved with and without water methanol.

Z123 Stock Z1, stock turbo, stock muffler, stock EFI map, TD large capacity intercooler/ charge tube, no H2O

EngSpd	STPPwr	STPTrq	BSFA_B	FulA_B	AFRA_B	ExhPrs	BoostP	FulPrA
RPM	CHp	Clb-ft	lb/hph	lbs/hr	Ratio	psig	psig	psig
7800	186.8	125.8	0.531	92.7	11.3	16.1	11.2	54.0
7900	187.2	124.5	0.519	90.7	11.5	16.3	11.0	53.9
8000	186.1	122.2	0.522	90.7	11.5	16.2	10.8	53.5
8100	183.8	119.2	0.540	92.6	11.2	15.9	10.3	53.2

The D&D TD quiet muffler flowed plenty of air to keep power high and turbo backpressure low, yet dB was low enough to probably pass as being stock on most trail systems—even at WOT. Here's the Z1 with no water/ methanol on 93 octane gas that Ben and I purchased locally.

Z142 Stock Z1, stock turbo, D&D TD quiet muffler, TD 94 octane map, no H2O

EngSpd	STPPwr	STPTrq	BSFA_B	FulA_B	AFRA_B	Air_1c	BoostP	FulPrA
RPM	CHp	Clb-ft	lb/hph	lbs/hr	Ratio	CFM	psig	psig
7500	253.4	177.5	0.554	131.3	10.7	323	21.3	63.8
7600	256.2	177.0	0.544	130.5	10.8	326	21.4	64.0
7700	258.2	176.1	0.537	129.7	11.0	330	21.6	64.2
7800	261.4	176.0	0.533	130.3	11.1	332	21.6	64.3
7900	263.9	175.4	0.529	130.5	11.1	334	21.6	64.2
8000	265.0	174.0	0.534	132.1	11.0	336	21.5	64.1
8100	266.2	172.6	0.532	132.3	11.1	337	21.7	64.2
8200	267.6	171.4	0.531	132.6	11.1	338	21.9	64.0
8300	267.3	169.1	0.537	134.0	11.0	339	21.7	63.7
8400	266.6	166.7	0.538	133.7	11.0	340	21.4	63.6

Here's the same D&D TD quiet muffler, still with stock turbine outlet housing. The same lakerace map is used with water/ methanol injection allowing 10 psi higher boost pressure w/o deto on the same 93 octane fuel! The wastegate was shimmed to help create 30 psi boost. Here, the methanol injection system provides additional fuel to keep LM1 A/F reading at around 12/1. The low BSFC number considers injected fuel only, and the methanol (not measured by the dyno) would effectively raise that number. The LM1 wideband considers all sources of fuel in determining A/F ratio. This is incredible HP with the quiet D&D muffler on pump gas. Ben says this is for dragracing on the lake.

Z140 Stock Z1, stock turbo, D&D TD quiet muffler, TD lakerace map, shimmed wastegate, water methanol injection tuned for max power on pump gas

EngSpd	STPPwr	STPTrq	BSFA_B	FulA_B	Air_1c	LamAF1	BoostP	FulPrA
RPM	CHp	Clb-ft	lb/hph	lbs/hr	CFM	Ratio	psig	psig
7500	305.5	213.9	0.371	106.1	382	12.5	30.2	72.7
7600	308.1	212.9	0.368	106.1	383	12.4	30.0	72.6
7700	309.0	210.8	0.370	106.8	384	12.2	29.8	72.4
7800	308.7	207.8	0.368	106.4	384	12.2	29.6	72.1
7900	307.5	204.4	0.380	109.2	385	12.1	29.5	71.9
8000	306.2	201.0	0.386	110.5	385	12.0	29.3	71.8
8100	304.3	197.3	0.387	110.0	385	12.0	28.9	71.6
8200	302.6	193.8	0.398	112.4	386	11.9	28.9	71.4
8300	301.8	191.0	0.399	112.5	386	11.9	28.8	71.4
8400	300.5	187.9	0.409	114.6	386	11.8	29.1	70.7

This is the same setup, but with the D&D quiet muffler removed and replaced with a Turbo Dynamics straight pipe. 315 plus HP on pump gas, and we must be about out of turbo!

Z137 Stock Z1, stock turbo, TD straight pipe w/o muffler, TD lakerace map, shimmed wastegate, water methanol injection tuned for max power on pump gas

EngSpd	STPPwr	STPTrq	BSFA_B	FulA_B	Air_1c	LamAF1	BoostP
RPM	CHp	Clb-ft	lb/hph	lbs/hr	CFM	Ratio	psig
7600	311.5	215.3	0.394	115.3	384	12.3	29.8
7700	313.7	213.9	0.390	114.9	386	12.3	29.5
7800	315.2	212.2	0.386	114.2	386	12.2	29.6
7900	315.1	209.5	0.386	114.2	386	12.2	29.5
8000	312.6	205.2	0.391	114.7	387	12.2	29.3
8100	311.4	201.9	0.394	115.0	387	12.1	29.0
8200	310.7	199.0	0.400	116.4	388	12.1	29.0
8300	309.0	195.5	0.407	117.9	389	11.9	28.7
8400	308.6	192.9	0.414	119.8	389	11.9	28.2

Next, Ben removed the stock cast iron turbine housing outlet and installed the BMP "divorced wastegate" welded sheetmetal turbine outlet housing that keeps the turbine outlet separate from the wastegate outlet until just before the junction of the muffler inlet pipe. This was tested with the BMP glasspack muffler without methanol and with the same tuning that gave us 250 HP with the D&D TD quiet muffler, and we made 258 HP. This was the result of higher airflow combined with fixed fuel flow (leaning out mixture a bit), but at max power of 315 the turbo seems to be the limiting factor. A larger turbo can surely make good use of the higher flowing exhaust, or perhaps we could have made 300+ HP with the D&D quiet muffler, with less boost.

We should have tested the D&D quiet muffler with lower octane/ boost settings, but having been understandably wrapped up with big power levels, more practical but still powerful trail settings for 87/ 89 octane were forgotten. But now after making good power with the BMP divorced wastegate/ glasspack muffler, here is the BMP exhaust with Ben's "Eco trail map". Just a few more PSI boost than stock, but 40 more HP!

Z153 Stock Z1, stock turbo w/ BMP divorced wastegate outlet housing, BMP glasspack, ECO low octane trail map, no water methanol needed.

EngSpd	STPPwr	STPTrq	BSFA_B	FulA_B	Air_1c	LamAF1	BoostP	FulPrA
RPM	CHp	Clb-ft	lb/hph	lbs/hr	CFM	Ratio	psig	psig
7800	215.0	144.8	0.468	94.2	287	12.3	13.3	56.2
7900	217.8	144.8	0.472	96.1	290	12.3	13.4	56.4
8000	219.2	143.9	0.481	98.6	294	12.3	13.6	56.5
8100	221.1	143.4	0.488	100.9	295	12.2	13.8	56.7
8200	221.3	141.7	0.488	101.0	298	12.1	14.0	56.7
8300	221.0	139.9	0.508	105.0	299	11.8	13.7	56.7
8400	219.9	137.5	0.527	108.3	299	11.6	13.8	56.7

Operating any engine on pump gas at nearly 5 HP per cubic inch seems like an amazing feat. And even though we had zero knock or issues during our test session with any of the Turbo Dynamic tunes, a steady 300 HP diet can't do much for sled/ engine/ turbo longevity. The first flicker of the TD knock light requires immediate lifting—allowing the engine's 180 HP ECU to try to protect itself from inevitable occasional 300 HP deto invites long term, expensive problems. And remember—a few clicks of knock can send a hot running engine into preignition, which can be silent (for a few seconds before loud and catastrophic failure of components…) but way more destructive than detonation! So the prudent Z1 tuner will surely spend most of his drive time at more reasonable boost levels. That last dyno test with less than 14psi of boost and 220 plus HP represents a stout 40 HP over stock. Driving a Z1 on a daily basis with safely tuned 220+ HP on tap should provide great enjoyment with way less concern for reliability/ longevity. And for those who limit their time at WOT, perhaps 250+ HP is OK, but pay close attention to that knock light! My opinion is save the big 300+ HP stuff for occasional short lake blasts. And even though we made over 300 HP on pump gas on the dyno, spending a few extra bucks for race gas when running 300 HP is very cheap insurance.