Nitrogen Assisted Nitrous Oxide applied to DynoPort SkiDoo XP800 single pipe mod engine.

Weight conscious dragracer Rich Daly (owner of DynoPort and Mad Scientist Ceramic Coatings) thought it might be fun to try to achieve three cylinder ProStock 1000cc HP out of his 800cc twin asphalt dragracer using Nitrous Oxide power adder.

The best PS1000 triples tuned here are currently making 275-285 HP, and Rich figured that if he could achieve similar HP with less weight he could have a performance advantage racing in some class where he might compete against them. But this would require adding 50 HP per cylinder, which is a daunting task even on large displacement twins. Forcing 50 HP worth of N2O through each fogger nozzle typically requires high cylinder [bottle] pressure (usually 800-1000 psi) to overcome the restriction of the tiny orifices in the nozzle bodies. Winter tuning for big HP is especially difficult—cold N2O cylinders have low "head" pressure (as low as 300 psi in cold temps) and as temperature rises, N2O cylinder head pressure rises accordingly all the way to 1000 psi plus on very hot days (here is a chart that shows the relationship between temperature and pressure… www.nitroussupply.com/bottletemp.php). Then, as nitrous oxide is consumed during a run, the N2O cylinder temperature drops as more nitrous oxide vaporizes inside the cylinder to make up for the lost volume.

The common means to achieve optimal N2O pressure is with electric heaters or, to my dismay mapp gas or propane torches. Drag sleds often lack the battery/ alternator capacity to generate the energy required to maintain the desired cylinder temperature/ head pressure. And applying 3000 degree F flames to 6061 T6 aluminum cylinders that anneals (loses much of its tensile strength) at 500 F makes me cringe. In the dyno, I insist that tuners use hot water or hot air to bring N2O pressure to what they feel is optimal, no torches allowed. Those of us who've seen photos of exploded compressed gas cylinders can appreciate the havoc they wreak on metal and flesh, not unlike what happens when IEDs are ignited by evildoers in Iraq and Afghanistan.

The obvious pain in the butt for N2O tuners searching for maximum HP is unavoidable variation in N2O cylinder head pressure—tuning varies widely as pressure changes. Since the flow of added fuel by fogger systems is fixed, mixture will enrichen gradually as temp drops during a run causing power to drop. Or worse yet, if N2O pressure rises then mixture will be too lean with disastrous results from deto and/ or preignition.

Moderate consistent power can be made with regulated n2o (constant lower n2o pressure), like used on Boondocker systems. Boondocker EFI n2o systems also will adjust fuel flow to match n2o pressure, preventing mixture from going fat as pressure drops. But for making the highest HP high pressure N2O with fogger nozzles has been easiest for us at DTR.

Because of our experience here, Rich Daly opted for a NX (Nitrous Express) system with NANO nitrogen assist to maintain constant high pressure with no cylinder heating.

We like the NX systems because of the high quality, higher flowing braided stainless steel fuel and N2O hoses with anodized AN fittings. The black plastic air-shock hose used by most N2O systems are seemingly restrictive especially when the brass fittings are overtightened a few times, causing the ID to be crimped. Tuners using that tiny hose sometimes wind up with no N2O jets at all, letting the N2O freeflow into the engine, with ultimate HP still lower than hoped for. NX also boasts of the higher flow capacity of their solenoids and fogger nozzles. But since we achieved the desired HP on Rich's engine before we ran out of n2o flow, we can't comment on the ultimate HP capacity of the standard NX solenoids and nozzles.

The NANO (www.nanonitrous.com) system consists of a custom machined N2O cylinder valve (to replace the stock valve) with a 1/8" npt fitting that is connected by drilled passages to the bottom of the valve next to the siphon tube. This modified valve is connected by a high pressure hose to a small piggy-back high pressure nitrogen cylinder (3-4000 psi) that is regulated down to an indicated (by the NX gauge) 900 psi. The idea is to use nitrogen (N2) to blanket the liquid n2o and provide a constant 900 psi head pressure regardless of temperature or cylinder contents. The N2 does not mix with the N2O—it's only used as a constant high pressure propellant. This way we would have the pressure necessary to achieve the desired HP whether there was 2.5 or .5 lb on N2O liquid in the cylinder. However, it s noted that in very hot weather the standard N2O head pressure can exceed 900 psi and goof up the tune. So when temperature/ head pressure is high, the N2O cylinder must be cooled with cold water to drop pressure properly (the NANO kits come with N2O cylinder temp monitoring adhesive strips to help monitor that in hot weather).

Normally Aspirated baseline.

With Rich's XP800 engine bolted to the rubber mounted dyno engine plate (out of the sled) and N2O hardware acquired and connected, we began our baseline testing with the engine as optimal for operating on race gas, with no power adder. Rich runs his engine with open bored out stock carbs, and we had no airbox to give us mechanical airflow measurement.

Here is the XP800 with Rich's ported stock bore and stroke (measured by me at Rich's insistance). Rich uses Chuckaroo billet head (unusually shrink-wrap stock appearing) at 14.5/1 with .040" squish. The ECU is programmed with about 3 degrees additional timing advance. On this baseline with max HP jetting, Vforce reeds are used. A DynoPort Y pipe and single pipe with internal stinger is used, with a short open 1 5/8" stinger in place of the muffler to save weight. We began the test session with a muffler in place, then switched to the open stinger (to save weight). The open stinger just matched the muffler for HP.

Baseline max HP NA, V Force 3 reeds

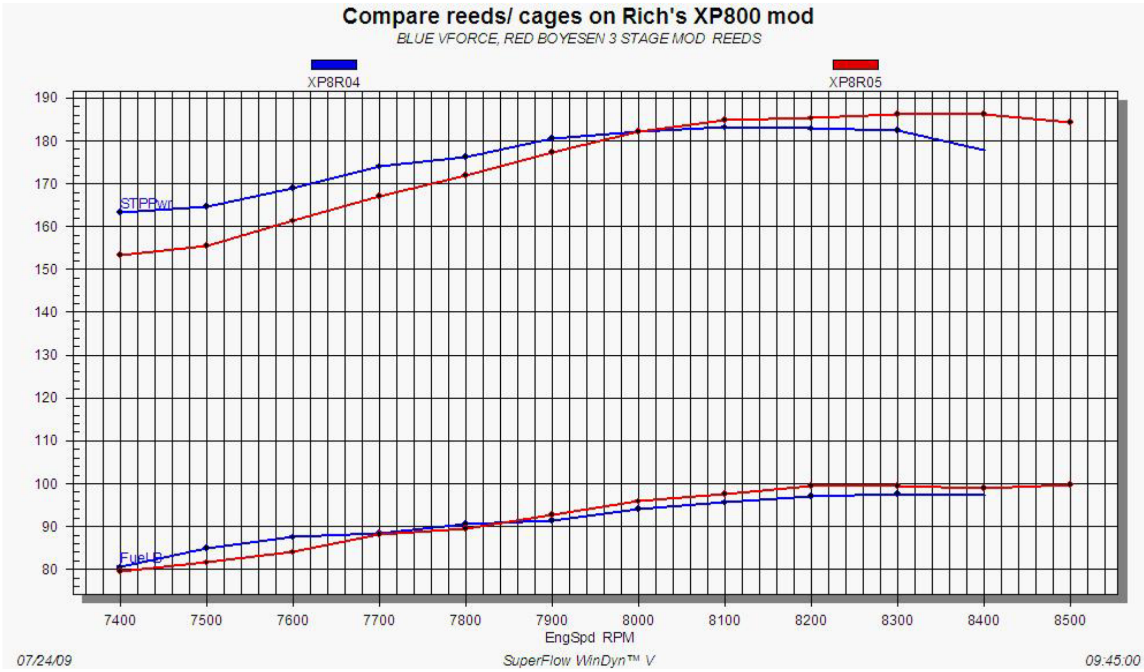
EngSpd	STPTrq	STPPwr	Fuel B	BSFC B	AirTmp	TsTim2	BaroP
RPM	Clb-ft	CHp	lb/hr	lb/hph	degF	second	in/Hg
7400	115.9	163.4	80.5	0.534	81	0	28.89

7500	115.3	164.7	85.0	0.560	81	0.5	28.89
7600	116.8	169.0	87.5	0.561	80	1.2	28.89
7700	118.7	174.0	88.5	0.552	81	1.8	28.89
7800	118.7	176.3	90.7	0.558	81	2.2	28.89
7900	120.1	180.7	91.5	0.550	81	3.2	28.89
8000	119.6	182.1	94.1	0.561	81	3.9	28.89
8100	118.7	183.1	95.6	0.567	81	4.4	28.89
8200	117.2	182.9	97.1	0.576	81	5.1	28.89
8300	115.5	182.5	97.6	0.581	81	5.8	28.89
8400	111.3	178.0	97.4	0.595	81	6.5	28.89

Next Rich removed the Vforce 3 reed cages and installed a set of three stage (three layers of petals) Boyesen reeds in their cast aluminum cages designed specifically for mod XP800 engines. The Boyesen reeds lost low end airflow and HP, but picked up airflow and three HP at high revs. Sean Ray suggested that the Boyesen three stage petals are probably more flexible allowing higher airflow through the heavily ported XP800 at peak revs. But it looks like they are hanging open too long at low revs WOT allowing some crankcase air to sneak back out through the carbs (picking up more fuel in the process) instead of being forced up the transfer ports before the reeds finally slap closed. The HP/ fuel curve show clearly what is happening, and if we had our wideband measuring mixture on these runs we might have seen richer low RPM A/F with the Boyesen reeds even with lower fuel flow lb/hr. This shows how changes in reeds/ reed stiffness can affect engine performance. Tuning performance engines for max HP deserves this sort of evaluation, right along with optimizing timing and fuel flow.

Baseline max HP NA, Boyesen reed cages w/ 3 stage petals for mod engines

EngSpd	STPTrq	STPPwr	Fuel B	BSFC B	AirTmp	TsTim2	BaroP
RPM	Clb-ft	CHp	lb/hr	lb/hph	degF	second	in/Hg
7400	108.8	153.4	79.6	0.563	81	0	28.89
7500	108.9	155.5	81.6	0.570	81	0.3	28.89
7600	111.5	161.3	84.0	0.565	81	1.1	28.89
7700	113.9	167.1	88.2	0.573	81	1.8	28.89
7800	115.8	172.0	89.6	0.565	81	2.3	28.88
7900	117.9	177.3	92.7	0.567	80	3.2	28.88
8000	119.7	182.3	95.9	0.570	80	4.0	28.89
8100	119.8	184.8	97.6	0.573	81	4.6	28.89
8200	118.7	185.3	99.6	0.584	81	5.3	28.88
8300	117.8	186.2	99.6	0.580	80	5.9	28.88
8400	116.5	186.3	99.0	0.577	80	6.6	28.88
8500	113.9	184.4	99.7	0.587	80	7.4	28.88



Next, we detuned the engine with three degrees less timing and a Chuckaroo head with two points less compression. Also main jets were bumped up 80 numbers. The higher fuel flow combined with reduced compression and retarded timing dropped BSFC to a safer level NA, something wise to do when planning to add N2O.

Baseline, detuned for adding N2O

EngSpd RPM	STPTrq Clb-ft	STPPwr CHp	Fuel B lb/hr	BSFC B lb/hph	LAMAF1 Ratio	AirTmp degF	TsTim2 second	BOOST IN HG
7400	102.9	144.9	85.8	0.644	13.1	82	0	7
7500	102.6	146.5	88.5	0.657	13.1	81	0.5	7.2
7600	104.2	150.8	89.9	0.648	13.0	81	1.1	7.5
7700	105.4	154.5	91.2	0.641	12.9	81	1.6	7.8
7800	108.3	160.8	94.1	0.636	12.9	81	2.3	8.3
7900	109.2	164.2	96.9	0.641	12.7	81	3.0	8.6
8000	110.1	167.6	96.7	0.627	12.6	81	3.7	9.0
8100	110.6	170.5	99.8	0.636	12.5	81	4.6	9.2
8200	110.1	171.9	99.7	0.630	12.5	81	5.0	9.4
8300	108.7	171.8	101.4	0.642	12.6	82	5.7	9.6
8400	106.4	170.2	100.5	0.643	12.8	82	6.7	9.9
8500	103.9	168.1	98.5	0.639	13.2	82	7.4	10.1

Tuning with nitrous

Rich drilled and tapped his Boyesen boots/ aluminum reed cages to accept the NX fogger nozzles. Rich also installed a larger 1 ¾" ID stinger and we closely monitored pipe backpressure (shown as Boost inches of mercury). Using VP 120 motor octane import fuel (used successfully by the highest HP turbo sleds tuned here), we started with the N2O and fuel jets recommended by the NX tech for 50 HP/ cylinder (assuming correctly that their recommended jetting was going to be very conservative). So from there we worked our way up a few thousandths at a time, listening carefully for clicks of deto. Pass after pass we monitored N2 regulator outlet pressure/ N2O cylinder pressure and it stayed rock solid at 900 psi all the way down to 1200 psi N2 cylinder pressure at which point we changed to a full N2 cylinder. NANO recommends a fresh N2 refill with each N2O refill (refills available at welding supplies or paint ball or scuba refill places (air is said to work as well a N2 since air is 80% N2).

Here's Rich's first baseline N2O tune. Note that his pipe backpressure is lower than detuned NA backpressure.

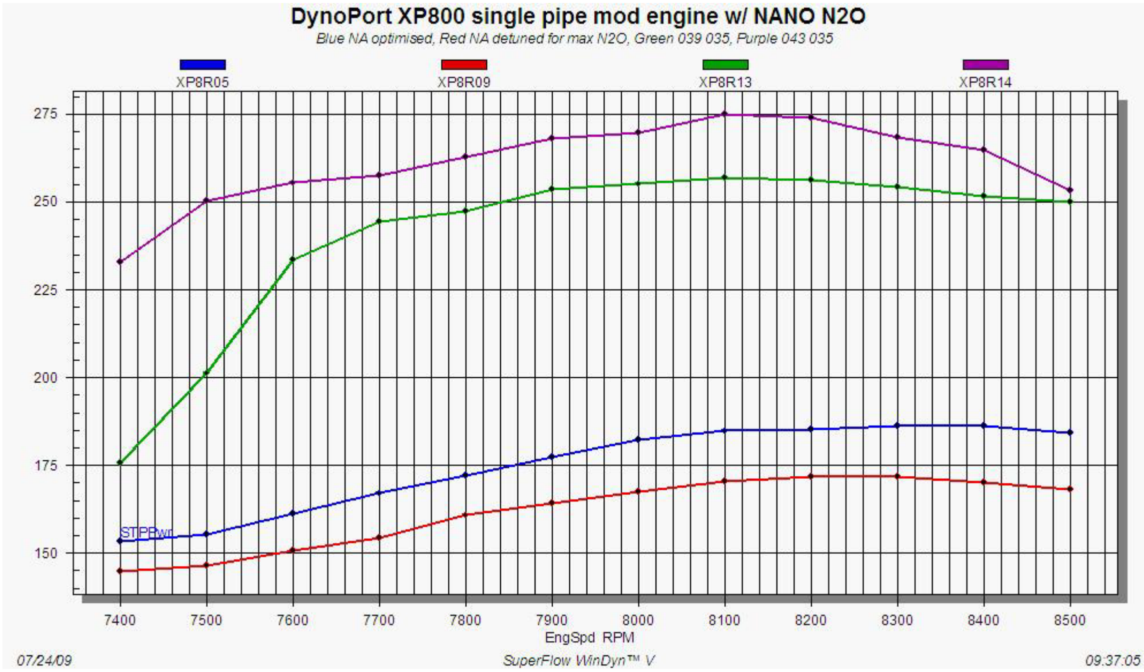
.039 N2O/ .035 Fuel

EngSpd	STPTrq	STPPwr	Fuel B	BSFC B	LAMAF1	AirTmp	TsTim2	BOOST
RPM	Clb-ft	CHp	lb/hr	lb/hph	Ratio	degF	second	IN HG
7400	124.8	175.9	127.5	0.790	15.6	85	0	5.8
7500	140.9	201.2	133.6	0.722	15.7	84	0	6.6
7600	161.4	233.6	155.0	0.722	11.3	86	1.4	8.0
7700	166.8	244.5	161.7	0.720	10.8	86	1.7	8.4
7800	166.6	247.4	160.4	0.706	10.6	86	1.8	8.7
7900	168.6	253.6	163.2	0.700	10.1	85	2.2	9.0
8000	167.5	255.2	164.7	0.702	10.0	85	2.4	9.1
8100	166.7	257.1	159.1	0.673	9.9	85	2.8	9.3
8200	164.2	256.4	163.6	0.694	9.8	85	3.0	9.4
8300	161.0	254.4	161.0	0.689	9.9	86	3.4	9.6
8400	157.3	251.7	163.7	0.709	9.9	86	3.7	9.7
8500	154.5	250.0	166.2	0.725	9.9	86	3.9	9.8

Looking at the wideband A/F ratio and high fuel flow, we bumped up the N2O jets to .043" and Rich made his PS1000 power target.

.042 N2O/ .035 Fuel

EngSpd	STPTrq	STPPwr	Fuel B	BSFC B	LAMAF1	AirTmp	TsTim2	BOOST
RPM	Clb-ft	CHp	lb/hr	lb/hph	Ratio	degF	second	IN HG
7400	165.3	233.0	144.8	0.681	13.8	87	0	7.3
7500	175.3	250.3	156.2	0.683	11.7	86	0.8	8.3
7600	176.5	255.4	157.0	0.673	11.4	86	1.0	8.5
7700	175.7	257.6	154.6	0.657	11.2	86	1.1	8.7
7800	177.0	262.9	152.6	0.635	10.9	86	1.2	8.9
7900	178.3	268.2	155.0	0.633	10.5	86	1.7	9.4
8000	177.0	269.7	156.8	0.637	10.4	86	1.8	9.5
8100	178.4	275.1	158.5	0.631	10.3	86	2.2	9.7
8200	175.6	274.1	162.0	0.647	10.2	86	2.5	9.8
8300	169.9	268.6	163.0	0.665	10.2	86	2.9	9.9
8400	165.6	264.9	162.2	0.671	10.2	86	3.2	9.9
8500	156.6	253.4	164.6	0.712	10.2	85	3.4	9.9



Some observations:

Note how the wideband readings are extremely fat-looking with N2O. Remember this is total fuel flow from carbs and through the fogger nozzles. Now I'm wondering, is the VP Import the best gas for big N2O power? The reid vapor pressure is comparatively low, and it's possible that the fuel is not vaporizing well at close to –100 F. It's dandy with boosted engines, which typically have high inlet temps. Even the best liquid-air iced intercoolers have intake charge temps about ambient. The rich-looking A/F wideband reading might mean lots of the VP Import is blowing through the combustion chamber in globs, and not vaporizing until it makes it out into the hot exhaust pipe before it crosses the O2 sensor in the pipe outlet. We never heard deto but it took lots of fuel to make 275 HP (251 observed uncorrected HP) safely. Perhaps a higher reid vapor pressure fuel like Sunoco Maximal would be better—a bit lower motor octane but much easier to vaporize.

We have installed in Rich's setup an NX delay timer, which "eases on" the N2O and fuel as gradually as you like (sort of like tuneable traction control for the asphalt). Here, to make it easier for the dyno to regain control of the engine after hitting the button before the dyno run we set the timer to delay the full power—beginning at 20% then being full on in one second. The problem here is the relatively low 5 psi delivered by the inline NX pump comes on way slower than the 900 psi of the N2O. That results in an initial lean mixture (we saw as lean as 17/1 on first hit as the dyno loaded the engine). Often I hear nasty clicks of deto when this initial hit occurs, but goes away quickly. But today there was none, probably because of the 120 motor octane. But a better fix would be to isolate the fuel solenoid and have that go full-on while the delay timer eases on the flow of N2O to the engine. That would require some wiring changes that I hope Rich will incorporate in the sled.

Note that with the optimized stinger diameter (maintaining low center section pressure) the HP peak RPM is similar with and without N2O. Usually, without optimizing pipe backpressure we typically see the HP peak HP RPM climb to higher revs. But here, the larger stinger allows the exhaust to exit quickly, spending less time heating the pipe which in turn heats the exhaust less (and allows those inevitable active radicals to escape from the cylinder instead of creating deto). Also more cool intake charge is likely sent into the pipe, not trapped, further causing pipe center section temp (and the speed of sound) to be similar or even a touch lower than NA.

Also, being greedy and [before thinking about the possibility of the fuel not vaporizing well] suspecting that 165 lb/hr of fuel flow should support 290 CHP, we installed even larger N2O jets we began a final dyno test. At 7500 the engine was 20 HP stronger than it was on the 275 HP calibration. But at 7600 the engine appeared to preignite with no clicks of deto, wafting a quiet fireball out of the open stinger and singing the reed petals. Preignition occurs from the mixture igniting from a hot spot in the combustion chamber (ie: the splug ground strap) it can occur as early as BDC when the transfers and exhaust ports are open. That would explain the fireball whooshing out the stinger outlet and the singed reed petals. There was no damage to the engine itself since we caught it early enough. It is likely that the lean initial N2O/ fuel mixture overheated the plug ground strap which in turn ignited the volatile fuel/ air/ N2O mixture near BDC. Perhaps sparkplugs with no ground straps (like Mercury Marine outboard plugs or GM NASCAR plugs) would eliminate the most likely source of preignition. Or, just making sure the fuel gets to the engine on time, or even just a touch earlier than the N2O would be beneficial.

Rich did bring this asphalt sled to the July '09 Cicero, NY ESTA race he helps sponsor. But he managed to grind one of his big toes down to the bone and cartilage by accidentally dragging one of his new prostock bike boots down the asphalt on an ill-fated qualifying run NA. So meaningful performance results of the N2O package will have to wait until his injured toe either heals or gets removed (which would save several more valuable ounces of unnecessary weight).