

DYNOTECH

JOURNAL OF SNOWMOBILE PERFORMANCE AND TWO STROKE TECHNOLOGY

BATTLE VI OF OLD FORGE

This year, since they adopted a magazine-like format, American Snowmobiler Magazine is available on newsstands throughout North America, so it should be accessible to most DynoTech subscribers. Individual issues or annual subscriptions to American Snowmobiler are also available by calling 612-738-1953. The Spring issue of American Snowmobiler has all of the field performance details of Battle of Old Forge VI, including 60 ft, 660 ft (1/8th mile), and 1320 ft (1/4 mile) ETs and MPH of the four 600 class and four 800 class machines we tested this year. The two stock and two "dealer prep" runs are all listed. These figures were garnered by the use of a Port-A-Tree system rented from International Championship Series of Grass Racing, and set up by Jeff Stefanick of Port-A-Tree and Tal Daiker.

In addition to the Port-A-Tree data, American Snowmobiler published shockingly quick 0-60 and 50-80 MPH times for each machine. These numbers were obtained with Jerry Bassett's Stalker radar gun connected to a lap-top computer. The Stalker program records each acceleration run on a disc, and the results can be compared graphically by time, speed, and distance traveled (1/4 mile or more). I'd never seen this program before--but after seeing it operate I'd say that it is a must-have tuning (and spying) tool for any serious track or lake racer.

As has been the case for the past several years, the four 600 class sleds and four 800 class sleds were dyno certified here on the C&H Dyno in Batavia, NY, about four hours from the Old Forge area. This is to ensure the sleds are stock and typical of what the consumer receives from the dealer. It's a pain in the butt for the Old Forge area dealers who participate in this premier annual shootout, but we must do this to keep things as fair as possible.

This year, the sleds arrived in two waves over two days before the shootout; Monday, George Taylor arrived at the dyno with sleds and guys from Smith Marine Ski-

Doo and Big Moose Yamaha/Arctic Cat. We dyno tested the Ski-Doos and Yamahas the first day.

This consisted of removing the drive clutch, aligning the engine's crankshaft to the shaft drive of the dyno, strapping down the chassis to our hydraulic table, and connecting the dyno drive shaft through the bellypan and onto the crank taper. The metered fuel line from the dyno is connected to the sleds' fuel pump(s) so that we can observe the fuel flow and BSFC. Where practical, the dyno airflow meter is attached to the airbox. The throttle cable is connected to the hydraulic dyno throttle control. Then, we do two 10-12 second acceleration tests, or "pulls" on each engine with stock factory jets and their own cooling systems intact. During extensive dyno evaluations, the engines are cooled with a thermostatically controlled to 80 degrees F water tank (consistent coolant temperature is critical for repeatability). The first test, done after about a twenty second part throttle light load warmup, would be considered "cold shot" HP. and the second run, done within less than a minute after the completion of the first test, would be considered a "hot pull" with engine coolant at 80-100 degrees F, and pipes preheated by the first run.

The outside air temperature during the test plays a great part in our usual dyno evaluations. Normally, we would adjust the factory installed main jets in accordance to the Mikuni slide rule, but as long as the engines run clean (leaner than 10-1 with no misfire), stock jets are used for Battle certification. Here, all we need to know is whether the engine is typical or not.

Assuming we get clean runs with no misfire, the computer printouts are compared with known stock engine data. If everything is OK, the machine is certified stock and locked back into the trailer until shootout-day. Prior to lockup, we check the engines' squish clearance with solder that's tagged and saved. Cranking compression is measured with a Snap-On gauge and documented.

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We tested the Cats first. The 800 ZRT, unchanged from last year, made 150 HP on its second hot pull and was removed. The 600 Cat was attached to the SuperFlow dyno next. We'd had some difficulty with the 600 ZRT tested in Vol 6 no. 4 with pipe leakage reducing back-pressure and power. This one must also have been built on the first day of production (see Cat's letter in FEEDBACK) because it exhibited similar leakage at the center flange and the power was less than expected at 113 CBHP on its second hot dyno pull. Even though there's not an official "bulletin" on ZRT 600 pipe leakage, we had the Big Moose Cat technicians remove, refit and silicone seal the pipe flanges like we did to ours (tested elsewhere in this issue). This was completed back at Big Moose under the watchful eye of George Taylor.

Next, the Yamaha V-Max 800 showed us a bit less power than last year's, and the V-Max 600 was about the same as last year's, though it had a new and improved single pipe combined with lowered compression.

We decided later that the V-Max 600 could run the "dealer prep" session with the factory optional GYT Kit that includes blown twin pipes, thinner two-piece (same as stock '95 and earlier) headgaskets, and a clutch kit (developed by Yamaha and Bender Racing during late November testing in Alaska). It would be impractical to change headgaskets between sessions, so we had Big Moose Yamaha install the thinner headgasket assembly prior to the shootout, and run that with the stock single pipe in the box-stock session. The higher compression would add maybe three or four HP to the single pipe HP). In light of the fact that the single piped Yamaha gave up 20-30 HP to the heavier 600 triples, though, it seemed OK.

On day two of the dyno certification, the new Polaris 800 Storm and XCR 600-SP were brought in from Don Haehl of White Lake Polaris/Mercury along with the 800 ZRT and 600 ZRT attended by Jon Martin and Spot St-Marie of Big Moose Yamaha/Arctic Cat.

We had seen the new Polaris models on the dyno in November when Rob Schooping from HTG Racing baselined their new machines prior to mod work. HTG's '96 Storm made 146 CBHP, as our Shootout Storm did. But although HTG's properly jetted XCR 600 SP made 118-119 CBHP, the new 600 brought in from White Lake Polaris only pulled 102 CBHP, even on three or four runs. We checked compression, ignition, crank indexing, all the basics, but we could find nothing amiss. So, we dispatched a courier to HTG Racing in nearby

Grand Island to borrow Rob's stocker's pipes, cannister, and CDI. Meanwhile, we pulled the XCR 600 SP off the dyno and continued our certification runs with the Ski-Doos.

The Ski-Doos were as expected--the Formula III showed us 120 HP and the Mach Z made 154, both of which would be 2-3% higher with "corrected" jetting for the 55 degree F degree air that day. The power level was as expected.

By the time we received Rob's pipes and CDI we were done with the Ski-Doos, and we reinstalled White Lake's new XCR 600 SP on the dyno. Unfortunately, even with replacement CDI and pipes the power output was still in the 102-ish range.

Meanwhile, conversations had been ongoing with Polaris factory technicians to attempt to troubleshoot the engine. After we tried everything we could, including rolling the timing around, it was decided that Polaris tech Rick Bates would fly from Roseau to New York and come to the dyno the following Monday to meet George Taylor and me with our underpowered XCR 600 SP.

Polaris FedExed us a complete new engine, in case we needed to cannibalize parts to make our stocker correct.

Monday AM, Rick Bates arrived with Don Haehl and George Taylor. On that morning, it was about 20 degrees F colder, which would equate to a couple of jet sizes leaner. We set the XCR 600-SP back on the dyno and tied the dyno cooling system to the engine. Surprisingly, without changing anything on the engine, it made 108 CBHP. At .80 lb/ hphr and with plenty of "wash" on the edges of the pistons, Rick knew it was still extremely safely jetted with the original factory installed 400 mains.

We worked our way down to what would turn out to be the new Polaris standard jetting specs. With 370-370-350 main jets installed, we did four repetitive dyno pulls. The first was a 200 RPM/sec acceleration test, the next two were slower, 100 RPM/sec runs, and the last was a 50 RPM/sec run, where power peaked at 8500 RPM. Total full load, full throttle time was approximately 60 seconds.

Suffice it to say, this was the most extreme case I'd seen of pipes' requiring extremely high temperature to be in tune with the engine (see FEEDBACK, "Backpressure"). Rick had described to us the four minute, full throttle, dyno runs on pump gas performed at Polaris Industries, and how survival for that length of time was necessary before the final spec was determined. This to ensure detonation-free operation for multi-mile WOT periods that some owners subject their machines to.

The 1996 600 cc and 800 cc sleds, as certified for Battle VI.

The 600's

The 800's

1996 XCR 600 SP *(See article)

Data for 29.92 in. Hg, 60 deg. F dry air
 Fuel Specific Gravity: .752
 Vapor Pressure: .20 Barometric Pressure: 29.51

RPM	CBT	CBHP	FUEL	BSFC	CAT
6500	60.1	74.4	75.9	1.04	52
6750	61.1	78.5	81.4	1.05	52
7000	67.9	90.5	76.3	.86	52
7250	70.4	97.2	81.4	.85	52
7500	70.7	101.0	85.1	.86	52
7750	68.5	101.1	84.4	.92	53
8000	60.7	92.5	82.2	1.07	53
8250	55.0	86.4	80.1	1.13	51

1996 SKIDOO FORMULA III

Data for 29.92 in. Hg, 60 deg. F dry air
 Fuel Specific Gravity: .752
 Vapor Pressure: .20
 Barometric Pressure: 29.72

RPM	CBT	CBHP	FUEL	BSFC	CAT
6500	69.4	85.9	70.2	.84	58
6750	72.5	93.2	76.7	.84	58
7000	73.2	97.6	79.6	.84	58
7250	74.3	102.6	80.0	.80	58
7500	74.8	106.8	84.5	.81	58
7750	74.7	110.2	89.0	.83	58
8000	78.8	120.0	90.2	.77	57
8250	74.0	116.2	91.3	.80	57

1996 ARCTIC CAT ZRT 600 *(See article)

Data for 29.92 in. Hg, 60 deg. F dry air
 Fuel Specific Gravity: .752
 Vapor Pressure: .15 Barometric Pressure: 29.96

RPM	CBT	CBHP	A/F	BSFC	CAT
6500	60.2	74.5	71.1	.95	50
6750	63.7	81.9	75.6	.92	50
7000	66.4	88.5	79.7	.89	50
7250	70.3	97.0	80.9	.83	50
7500	73.2	104.5	79.8	.76	49
7750	74.7	110.2	79.7	.72	49
8000	74.0	112.7	84.3	.74	49
8250	72.3	113.6	85.5	.75	49
8500	66.7	107.9	76.0	.70	49
8750	47.7	79.5	76.3	.95	49
9000	39.3	67.3	80.6	1.19	49

1996 YAMAHA V-MAX 600

Data for 29.92 in. Hg, 60 deg. F dry air
 Test: 100 RPM/sec Acceleration
 Fuel Specific Gravity: .752
 Vapor Pressure: .15 Barometric Pressure: 29.99

RPM	CBT	CBHP	FUEL	BSFC	CAT
6500	52.1	64.5	55.3	.85	48
6750	51.3	65.9	53.7	.81	48
7000	54.7	72.9	54.8	.74	49
7250	57.8	79.8	63.5	.79	49
7500	60.5	86.4	67.4	.77	49
7750	61.6	90.9	67.1	.73	50
8000	62.3	94.9	63.9	.67	49
8250	60.7	95.3	62.7	.65	48
8500	57.1	92.4	63.9	.68	47

1996 INDY STORM

Data for 29.92 in. Hg, 60 deg. F dry air
 Test: 100 RPM/sec Acceleration
 Fuel Specific Gravity: .752
 Vapor Pressure: .20 Barometric Pressure: 29.53

RPM	CBT	CBHP	FUEL	BSFC	CAT
6500	71.4	88.4	78.9	.91	52
6750	75.9	97.5	80.8	.84	52
7000	81.2	108.2	84.7	.79	52
7250	84.8	117.1	84.1	.73	53
7500	91.7	131.0	86.5	.67	53
7750	94.3	139.2	90.9	.66	54
8000	94.8	144.4	96.8	.68	53
8250	87.8	137.9	101.1	.75	54
8500	78.9	127.7	102.6	.82	54

MACH Z

Data for 29.92 in. Hg, 60 deg. F dry air
 Test: 100 RPM/sec Acceleration
 Fuel Specific Gravity: .752
 Vapor Pressure: .20 Barometric Pressure: 29.44

RPM	CBT	CBHP	FUEL	BSFC	CAT
6500	83.4	103.2	87.6	.87	58
6750	85.1	109.4	92.4	.86	56
7000	92.2	122.9	99.3	.83	58
7250	93.3	128.8	105.3	.84	58
7500	93.2	133.1	107.8	.83	58
7750	95.9	141.5	113.2	.82	57
8000	96.6	147.1	110.9	.77	57
8250	98.0	153.9	105.1	.70	57
8500	81.0	131.1	100.6	.79	57
8750	56.9	94.8	101.0	1.09	57

VMAX 800

Data for 29.92 in. Hg, 60 deg. F dry air
 Test: 100 RPM/sec Acceleration
 Fuel Specific Gravity: .752
 Vapor Pressure: .15 Barometric Pressure: 29.86

RPM	CBT	CBHP	FUEL	BSFC	CAT
7000	81.5	108.6	77.5	.71	43
7250	86.7	119.7	85.7	.71	42
7500	90.4	129.1	89.1	.68	41
7750	91.3	134.7	93.0	.68	42
8000	91.9	140.0	93.3	.66	43
8250	90.6	142.3	92.4	.64	43
8500	86.7	140.3	94.8	.67	43
8750	76.0	126.6	92.2	.72	44

1996 ZRT800

Data for 29.92 in. Hg, 60 deg. F dry air
 Test: 100 RPM/sec Acceleration
 Fuel Specific Gravity: .752
 Vapor Pressure: .15
 Barometric Pressure: 29.92

RPM	CBT	CBHP	FUEL	BSFC	CAT
7000	78.7	104.9	94.9	.89	39
7250	82.7	114.2	99.8	.86	39
7500	86.0	122.8	98.5	.79	39
7750	91.1	134.4	97.9	.72	40
8000	96.3	146.7	107.9	.72	40
8250	95.9	150.6	112.1	.73	40
8500	82.6	133.7	111.6	.82	39



When we do the field shootout at the drag strip behind the Ole Barn Restaurant in Inlet, NY, I don't have an awful lot to do but hang out, observe the festivities and talk to the dealers when they do their dealer prep. Jerry Bassett and George Taylor do all the work--communicating between the starting line and timing tower where Tal Daiker had

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**The Field
Shootout**

the Port-A-Tree equipment set up. This year, our pal Pete Webb served as an official "tech" inspector with fuel testing equipment to ensure that no illegal gasoline additives could be used. Pete also had electronic scales there, which were used to obtain the shootout sled weights. This year, along with the carbide studs and five gallons of gas, there was some snow in each sled's suspensions that may account for the higher weights printed in American Snowmobiler than those published in Dyno-Tech.

I will take credit for making the best early observation of the day. As Zach Taylor was making test passes on a stock Cat 440 ZR prior to the shootout to check out the Port-a-Tree, I was concerned that the Cat owners were celebrating 96 MPH quarter mile speed printouts on the 440 ZR stocker. George Taylor and I wondered where the turbo or nitrous bottle was hidden?

The 440 ZR Cat was run once more--this time with Jerry Bassett's Stalker aimed at it, and it was indeed about 10 MPH slower at 1/4 mile than the Port-A-Tree indicated. Some arguments ensued; was the new Cat really as fast as the Port-A-Tree printout said, and the radar gun was reading too low? Did you ever try to convince a cop that his radar gun was incorrect? A quick remeasuring of the finish line speed timing lights showed they were set up 60 feet apart instead of 66. Had this gone unnoticed, the 105 MPH 800s would have registered 115.5 MPH. Believe thy Stalker.

Once everything was in order, the box-stock runs were completed. The only surprise of this session was that the V-Max 600 performed so well compared to the more powerful but much heavier 600 triples. In deference to the hastily prepared XCR 600-SP, the revised factory jetting still didn't allow for ample pipe heat for decent power on the first two 1/4 mile runs. I had suggested to Zach that he run the Polaris as hard as he could on the return between runs one and two, but it was still off the mark. The problem was exacerbated by the stock clutch calibration allowing the engine to overrev to 84-8500 RM where it couldn't build HP, and if it can't build HP there it can't build heat as quickly as needed for this particular demonstration. The good news for Polaris fans was how much the White Lake Polaris guys were able to improve the XCR600SP's performance with "dealer prep"...

XCR 600 SP

By dropping down to lean and barely safe (for 1/4 mile at 2000 ft elevation) 320 main jets, the XCR 600-SP's power was improved, as was the engine's ability to build pipe temperature (and backpressure). An aggressive HTG multi-angle helix, four gram heavier weights, and a stiffer front spring were used. These aggressive clutch components had been selected based upon field testing done a week earlier by Don Haehl and HTG's Marc Buckley on Marc's new XCR 600-SP. In addition, a smaller 21 tooth top gear was installed in the chain case as suggested by the pre-shootout update bulletin. The gear change was somewhat controversial, drawing some criticism from the other dealers.

These changes resulted in the "most improved performance" award for the White Lake Polaris guys. As he did in the first portion of the shootout, Zach gave the XCR 600-SP the full throttle treatment on the 1/4 mle return run, this time muscling it through the deeper snow along the side of the plowed track to make the pipe temperature as high as possible. It was likely, however, that these aggressive components pulled the engine down too much, as the engine could have used a few more revs on the second hot-pipe run.

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Dealer Prep

ZRT 600

As was obvious from the box-stock performance, the ZRT 600 with its fairly decently sealed pipes came out-of-the-box very nicely. The holeshot was excellent, and Zach reported that revs were around 82-8300 RPM while accelerating. All Big Moose Cat man Mike Ross did to perk up the ZRT 600 for this application was to drop two main jet sizes, install a D&D Cycles unmarked grass drag rear helix, and an Arctic Cat orange/white front spring with two grams heavier weights.



VMax600

Big Moose Yamaha tech man Spot St-Marie installed the remainder of the Yamaha Gyt Kit; the factory blown twin pipes and the Bender/Yamaha clutch setup. The main jets were left stock. As stated earlier, the thinner headgasket provided with the GYT Kit had been installed earlier.

Formula III

Just as Doug and Tom Smith typically do for their lakeracer customers, the airbox was gutted and stock main jets left in place. All foam and baffles were removed--a modification that evidently increases airflow a bit, and surely reduces fuel flow because of the reduced pressure differential between the float bowls to the carbs' venturis. Zach had reported that the 600 Rotax triple had been overrevving by 2-300 RPM, so the front clutch "clickers" were adjusted two numbers, and a CrankShop custom machined (on their in-house Bridgeport CNC machining center) multi-angle helix.

800 STORM

Like the 600-SP, the Storm overrevved on the box-stock passes by about 4-500 RPM. Don and Marc left the main jets stock, and installed a HTG multi-angle rear helix, a new blue rear clutch spring, and a different front clutch that had been reshimmed tighter, with four grams heavier weights and a stiffer front spring. The Storm, however, mysteriously burbled on both dealer prep runs, a malady that was attributed later to a pinched vent hose between one carb and the airbox.

ZRT 800

Big Moose Cat technician Bob Deshaw installed 430 main jets and a D&D Cycles custom 62/54 multi-angle rear helix to help pull the revs down from 8300 to 8200 where the 800 Cats seem to accelerate best. Stock clutch weights were retained, and a yellow/ white front spring brought the engagement up to about 4300 RPM.

V-Max 800

Jack Lloyd of Big Moose Yamaha took the time to check the float level in each of the four 33mm Mikuni flatslides, and evened them up. The main jets were left stock. A Bender/Big Moose Yamaha stock dragracing clutch setup was installed, but it proved too aggressive for the conditions. The V-Max 800 underrevved at 7600 RPM on the dealer prep runs, which resulted in less than optimal performance.

Mach Z

Like the Formula III, the Mach Z was a bit overrich for this application at 2000 ft. altitude, and also overrevved by 250 RPM. Doug and Tom removed the foam and baffles from the airbox to lean the engine out, dropped the "clickers" one notch and installed another CrankShop multi-angle drag helix.

FINAL EPILOGUE FROM THE DYNO

Horsepower to weight ratio, good clutching and on-the-edge jetting win the shootout year after year. Last year, I believe that everyone got nailed with substandard or oxygenated gas.

The same jetting combos that detonated the Ski-Doos last year worked fine this year. The V-Max 4 slowed down last year with leaner jets, so the Big Moose guys opted to play safe with their jets this time.

Last Thoughts

CHANGES?

We can add enough time for our dealer prep sessions so that each sled can have a quick 2-300 ft post-prep burp to make sure the clutch changes are working as intended. It's tough to predict how these machines will react on the day of the shootout, and allowing the dealers to make short test runs seems to make sense.



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CHANGES continued

How about the 700's next year? This would require another day on the dyno, and lots more work and expense for the Old Forge area dealers. Write to American Snowmobiler to voice your interest in including this class of sleds. If you visit the Old Forge area this winter (or even in the summer) stop in to Van Auken's Inne to see Jayne and George Taylor, too. While you're there, eat some food and have a beverage or three.

Take the time to visit with the snowmobile dealers there, too. These guys work their butts off on this project. Their only real reward is the glory of the competition, the post-race party, bragging rights, and hopefully some additional parts and sled sales.

Don't forget the Big East Engine Builders that also support the Shootout with sponsorship bucks, parts and technical expertise. Bender Racing, the CrankShop, D&D Cycles and HTG Racing have become the premier Eastern racing engine builders for the four brands. Sure, there are some other good and creative engine builders in the East; but the aforementioned guys and their customers have made most of the headlines. I like to think that the common denominator of their amazing success, besides their being operated by smart, industrious people, is their proximity to our dyno testing facility.

Looking Ahead

Next December, look for the Polaris XCR 800-SP to be the dark horse favorite with less weight than the other 800s and 155-160 CBHP.

The new and a bit larger '97 Mach Z engine is reportedly 8 HP stronger. The V-Max 800 and ZRT 800 apparently aren't changing very much.

We'll have to wait and see if the the '97 two cylinder 600 Yamaha will be nearly as light as the Phaser, as rumor has that it will. Will it have as much HP as the ported and piped V-Max 600? If so, and the new chassis is around 500 lb with gas, it may have a power to weight ratio better than the other makes' triple 600's.

CONTROVERSY?

No shootout would be complete without controversy, but in this case, I'd say I don't think there was one.

While Polaris factory technician Rick Bates was at the dyno helping George, Don and me figure out the 600 SP, he noticed my assortment of tagged, "squished" lengths of 1/8" solder that had been used to measure and record each machine's piston to squish band clearance.

With dial calipers, Rick took the liberty (it was surely OK with me) to measure each solder piece, and was satisfied with the squish clearance measured on each machine except the Ski-Doo Mach Z. He was concerned about the .050" indicated at the tip of the solder that had been used to check the Mach Z's combustion chamber, stating that he felt that it was atypical. Rick Bates raised the issue of the Mach Z's .050" squish at a pre-shootout meeting at Van Auken's Inne on Wednesday night. The .050" squish is, technically, not "illegal", because it falls within the published ISR limits for that engine. But Rick's contention was that it's not what the average consumer receives out of the crate.

Rick's position is that ISR rules should not be a concern to us; ISR rules allow way too much leeway for "optimized" dimensions. Doesn't the ISR permit the "stock" Wildcat 700, for example, to have a squish clearance of from .075" to .045"?

Since we've never documented the squish clearance of other stock Mach Z's dyno tested here, we really don't know what's typical. Since the shootout, several Mach Z owners I've talked to tell me that .060 to .064 is more "typical", and ours is just a bit tighter than that. What about other subscribers' '96 Mach Z squish clearances? Did anyone else out there receive one like this? There is some variation in base gasket thickness that can easily account for that much difference, and we would attribute our shootout Mach Z's "tightness" to that.

Being maybe .010" "tighter" than normal would add maybe one or one and a half HP to a MachZ engine's output. Not a big deal; not enough to raise eyebrows during our dyno certification. But the principal is the issue. While he conceded that this had no effect on the outcome of shootout per se, Rick and the Polaris guys challenged me to report what he felt was an unacceptable inconsistency. Here it is.

Maybe next year we'll obtain squish dimensions from DynoTech subscribers around the country. We should make sure that each sled we select from the dealers' stock falls within a reasonable spec prior to the dyno certification. And afterwards, I'll be sure to hide the solder.

1996 Polaris 600 XCR SP

A 1997 Storm Brewing?

Here's the complete test data we obtained in our attempt to troubleshoot the XCR SP.

As mentioned previously, we had Rob Schooping's race XCR SP on the dyno for baselining. Here's Rob's Hot to Go 600 XCR SP dyno results with stock jetting.

96 XRC 600 SP 350 MJ

Data for 29.92 in. Hg, 60 deg. F dry air
 Test: 100 RPM/sec Acceleration
 Fuel Specific Gravity: .748
 Vapor Pressure: .36
 Barometric Pressure: 29.97

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
6750	53.5	68.8	54.9	118.8	9.9	.80	56
7000	60.5	80.6	66.7	128.7	8.9	.83	57
7250	64.1	88.5	71.5	138.0	8.9	.81	56
7500	66.5	95.0	78.7	147.0	8.6	.84	56
7750	71.1	104.9	80.9	155.0	8.8	.78	56
8000	73.2	111.5	80.7	156.8	8.9	.73	55
8250	74.7	117.3	83.3	160.6	8.9	.74	56
8500	73.6	119.1	87.4	167.1	8.8	.74	56
8750	68.1	113.5	94.1	171.4	8.4	.84	57

When we do our Battle dyno certification testing, we want to ensure that the engines are typical of what consumers purchase out-of-the-box. No more, no less. Based upon this early testing on HTG's stocker, and common sense, it was obvious that the SP we had for the shootout, at 102 HP, was not typical and not what Polaris had intended.

During our numerous troubleshooting calls to Polaris, their factory technician suggested that it was jetting and the duration of the dyno run (12 seconds each pass) that was contributing to the low power. They told me they had seen as much as 10 HP from a two jet size reduction in fuel flow. I was leery of that--having never seen such a phenomenon. But, I have learned in 1000 test sessions that it is wise to never say never. It was then that it was agreed that Shootout coordinator and Van Aukens Inne owner George Taylor would return to the dyno the next week with the XCR 600 SP, and Polaris' Rick Bates would fly in from Roseau to help us find the elusive power. As mentioned another engine arrived should we need extra stock parts.

When testing resumed Monday, with outside air temperatures 20 degrees F colder, the stock jets should have allowed performance equivalent to that which would be obtained with two sizes smaller jets. Without changing

anything on the engine, it made 108 CBHP, just as their technician predicted it would. Rick Bates knew it was still extremely safely jetted; it was at this time that we jetted down what would be Polaris' new standard spec.

With 370-370-350 main jets installed, we did the following repetitive dyno pulls. The first was a 200 RPM/sec acceleration test, and the next two were slower 100 RPM/ second runs. By the third, 'slower' pull, power peaked at 8250 RPM. Total full load, full throttle time was approximately 60 seconds.

96 XRC 600 SP 1st Run

Data for 29.92 in. Hg, 60 deg. F dry air
 Test: 200 RPM/sec Acceleration
 Fuel Specific Gravity: .740
 Vapor Pressure: .18
 Barometric Pressure: 29.97

RPM	CBT	CBHP	FUEL	BSFC	CAT
6500	56.2	72.0	53.3	.73	42
6750	60.5	77.6	59.7	.78	42
7000	65.1	86.8	64.3	.73	42
7250	67.3	92.9	69.6	.74	43
7500	69.7	99.5	70.1	.69	43
7750	68.8	101.5	75.8	.74	43
8000	60.7	92.5	84.5	.90	43
8250	56.0	88.0	85.9	.96	43
8500	50.8	82.0	89.2	1.07	43
8750	48.1	71.8	81.3	1.23	43

1996 XCR 600 SP 2nd Run

Data for 29.92 in. Hg, 60 deg. F dry air
 Test: 100 RPM/sec Acceleration
 Fuel Specific Gravity: .740
 Vapor Pressure: .18
 Barometric Pressure: 29.97

RPM	CBT	CBHP	FUEL	BSFC	CAT
6500	55.4	68.6	55.4	.80	44
6750	60.7	78.0	60.4	.76	43
7000	63.0	84.0	64.5	.76	44
7250	67.6	93.3	71.9	.76	43
7500	70.7	101.0	75.9	.74	44
7750	73.4	108.3	77.0	.70	43
8000	71.6	109.1	82.5	.75	43
8250	67.6	106.2	86.2	.80	43
8500	54.6	88.4	90.5	1.01	43
8750	49.2	82.0	90.9	1.09	42

1996 Polaris 600 XCR SP

A 1997 Storm Brewing?

continued

96 XCR 600 SP 3rd Run

Data for 29.92 in. Hg, 60 deg. F dry air

Test: **100 RPM/sec Acceleration**

Fuel Specific Gravity: .740

Vapor Pressure: .18 Barometric Pressure: 29.98

RPM	CBT	CBHP	FUEL	BSFC	CAT
6500	49.2	60.9	50.0	.61	44
6750	50.0	64.3	50.1	.77	44
7000	62.3	83.0	62.9	.75	44
7250	65.5	90.4	69.1	.75	44
7500	67.9	97.0	75.0	.76	44
7750	71.8	106.1	75.4	.70	45
8000	74.2	113.0	78.9	.69	42
8250	71.1	111.7	83.8	.74	43
8500	59.2	95.8	87.1	.90	44
8750	50.4	84.0	87.7	1.03	44

96 XCR 600 SP 4th Run

Data for 29.92 in. Hg, 60 deg. F dry air

Test: **50 RPM/sec Acceleration**

Fuel Specific Gravity: .740

Vapor Pressure: .18

Barometric Pressure: 29.98

RPM	CBT	CBHP	FUEL	BSFC	CAT
6500	47.8	59.2	50.7	.85	46
6750	51.2	65.9	64.1	.81	46
7000	60.1	80.1	64.3	.79	45
7250	62.3	86.1	68.5	.79	46
7500	66.9	94.5	74.3	.78	48
7750	70.2	103.6	78.7	.75	47
8000	72.8	110.9	80.2	.72	46
8250	74.8	117.5	82.9	.70	46
8500	70.4	113.9	85.2	.74	46

We've examined the performance capabilities of the triple-piped Ultra 680, which utilizes the early lightweight chassis. The equally new XCR 600 SP, with less power and the burden of the heavier Storm chassis was a mystery to us. Why use the Storm chassis?

After what I've seen from the dyno test results of several examples of this new Polaris model, I will make a Muhammed Ali-like prediction. In 1997, this will be the 800 Storm, the only difference will be the bore size.

It's as though this one was intended by someone to be 800cc to begin with. Here is some compelling evidence:

- Heavy duty, heavy weight muscle-sled Storm chassis.
- Storm-sized airbox with inlet holes larger than the 680 Ultra.

● Factory stamped triple pipes larger-than those on the 1996 Storm, with ultra low backpressure.

● Peculiarly oversize, 800-bore size cylinder sealing O-rings, allowing easy overbore and sleeving to accept 800 Storm pistons.

● Crankshop/HTG style colliding transfer ports, as opposed to the current Storm rear-aimed transfers.

● When bored and sleeved to accept 800 Storm pistons, with standard port timing and only 125psi of cranking compression, an overbored XCR 600/800 SP makes 155-160 CBHP immediately (no waiting for the pipes to build heat to make backpressure) at 8500 RPM on pump gas with the standard XCR 600 SP triple pipes.

This is 10 HP more than this year's 800 Storm, and more power with less weight than the 1996 ZRT800, Mach Z, or V-Max800. This is the performance deal of the year--40 extra HP for \$1000.

Based upon this evidence, shouldn't we expect the '97 800 Storm SP to have 155-160 CBHP, with the same weight as this year's XCR 600SP?

Here's one of the HTG modified XCR600SP's, bored and sleeved to 800cc, with stock pipes and Vforce reeds, 44mm Megatron carbs, and 125psi of cranking compression. 93 octane unleaded gas was used.

96 XCR 600 SP HOT TO GO 800 TRAIL BIG BORE 44 MEGATRON 6-2 CARBS-- 40 PJ V-FORCE REEDS--VENT TO STOCK AIRBOX

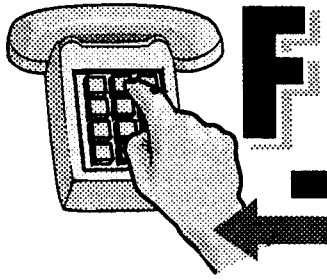
Data for 29.92 in. Hg, 60 deg. F dry air

Test: 100 RPM/sec Acceleration

Fuel Specific Gravity: .748

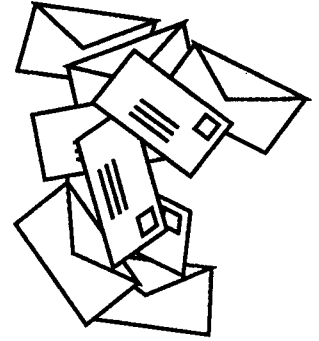
Vapor Pressure: .36 Barometric Pressure: 29.95

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
7000	74.2	98.9	67.6	159.1	10.8	.69	52
7250	73.8	101.9	70.5	166.2	10.8	.69	52
7500	86.6	123.7	81.2	186.0	10.5	.66	51
7750	95.7	141.2	95.4	202.3	9.7	.68	51
8000	99.0	150.8	100.7	207.6	9.5	.67	51
8250	100.8	158.3	102.1	210.9	9.5	.65	51
8500	99.4	160.9	101.6	216.1	9.8	.63	51
8750	95.3	158.8	102.0	217.5	9.8	.64	51



FEEDBACK

by Jim Czekała



We have many new subscribers who are just now reading this great information and really don't know my background. I'm orchestrating this newsletter from the control console of an extremely sophisticated dyno testing lab I built nine years ago. I'm not an engineer; I'm not qualified (as many who flaunt engineering degrees aren't) to evaluate mechanical devices on the merits of their engineering designs, but I'm absolutely the first guy wacko enough to build a public sophisticated computerized dyno testing lab for snowmobile engines.

In 1986 I bought a set of aftermarket twin pipes for a new snowmobile that made my sled run slower than stock. How could that be? My carb and clutch tuning prowess was questioned by the purveyor of the competition-looking welded-cone performance pipes. Undaunted, I needed to bring my sled to an independent dyno testing lab, even if it was located in Saskatchewan, to find this elusive power increase. After a great deal of research, it became obvious that there was no place to test my engine with these new pipes. Could I be the only lost soul who was in desperate need of independent snowmobile dyno information? Probably not. So, after a few months of research, I designed and built this revolutionary in-chassis dyno lab around a \$50,000 SuperFlow car engine instrumented, computerized dynamometer.

I learned about dyno testing 15 years ago from a pal, Clark Spiegel who had a small Stuska water brake for a few years, then sold it. He was a local two stroke guru who made a very good living building and tuning Mercury racing sleds for Steve Ognibene in the early '70's, and had his dyno in his garage. One day during the winter of 1979, I stood grinning next to Clark as he deftly worked the water valve and throttle, controlling the speed of my screaming 440 Kawasaki Invader engine bolted to the dyno three feet in front of us. Intense heat radiating from the shortened single pipe warmed our faces, and the pungent smoke from the baking fresh black header-paint made our eyes water. Clark manually controlled the small absorption unit to step and hold the engine to give us torque readings at various RPMs. I wasn't quite sure what Clark was doing with his torque gauge, pencil and calculator, but I knew it was fun. Plus, my Spiegel-modified Kawasaki Invader, at 78 HP, was faster than stockers which had 62. I

knew exactly what RPM to run it at, and the fact that it had even been on the dyno made me enjoy it even more. I was the only guy in our group who really knew how much power I had. I was hooked. But, in 1986 when I needed the dyno again, Clark had sold it. So, with help from some mechanically inclined friends, I built my own computerized dyno testing lab, which allowed us to test the engines without removing the engines from the chassis.

Since then, everything my very average brain has absorbed (including too many grams of tetraethyl lead) is the result of watching, thinking and discussing the test results as 1,000 engines have been run on the dyno. Nine years ago, for example, I had absolutely no idea what a needle jet really did to the air/fuel curve of an engine. Those who wrote carb tuning manuals didn't explain it very well. I had read that needle jets controlled A/F ratios from 1/2 to 3/4 throttle and that full throttle A/F ratios are controlled by the main jet and power jet. On the dyno, we found that needle jets have a most profound effect on full throttle A/F ratios at low velocity, low RPM, WOT. At high RPM, WOT it was partially needle jets plus main and power jets. I had no idea, nor did anyone else in the snowmobile industry (except some smart guys inside the factories who kept it all to themselves), what the Brake Specific Fuel Consumption numbers on our printouts meant. This fun new SuperFlow dyno gave us all that information, but no one hanging around here knew what that stuff meant. But, we all knew horsepower. And, we remembered all of our many foul-ups. After a bushel of detonated pistons, we had established kind of a pattern on fuel flow and detonation that USUALLY still works today. Nine years ago, John T. Cowie had the first double cylinder melt-down on the dyno messing with flat-slide carbs on his then-brand new Indy 400. I believe it was .47 lb/ hphr on pump gas for eight seconds. Die and learn. Nine years later, just as we thought we were getting pretty smart with all of this instrumentation, we had our second double melt-down. Once again, John T Cowie was the poor devil who had the dubious honor, this time with his brand new 680 Ultra. Don't worry, though. John T will be back again when he buys his next new sled. He's addicted like we all are.

Nine years ago, the information we were learning here was needed by everyone, but not many realized what we had. Tim Bender became addicted to this neat tun-





ing tool that none of his competitors knew about or had access to. Although Tim very likely would have won many oval races on that awful Exciter on his field tuning, driving skills and chassis setup skills alone, I like to think that his being able to optimize every facet of his engine program here helped him become the great success he is.

I really have had an enviable seat at the dyno control console for all of these years. As customers and pals have tested and made their own changes between runs, I've been free to spend time thinking about what's happened, and why. There is a long list of smart guys who have been here, tested and learned and shared experiences with me and helped me to understand things. I have the great, great fortune to have Kevin Cameron's ear when I see something new or weird on the dyno. Kevin says that he appreciates the fact that I have a unique perspective on engine performance; virtually everything I now know was learned at this dyno testing facility, combined with feedback from the field results of the many people who first dyno tested, then raced or trail rode their dyno tuned engines.

Today, most racers use sophisticated testing equipment like ours to test and tune with, or at least tuning information gleaned from such equipment. I don't hear the "you don't race dynos" BS any more. I believe it was in the fall of 1987 that I heard that for the last time, just before the top three finishers out of thirty entrants in Open Mod-Stock at the NYS Grass Drag Championships had tuned on our dyno the day before the event.

Today, Midwest Dyno Service in Joliet, IL, Calden Engineering in Jay, ME, Eagle Dyno Service in Mauston, WI, and Jaws Performance in Ottawa, ONT are public computerized dyno testing labs that are satisfying the needs of snowmobile performance aficionados in those areas.

One important missing piece in our quest for information is a high altitude, computerized public testing facility. My pal Bill Davis, who lives a mile high in Colorado, is extremely savvy on technical issues involving snowmobile engines. Bill has done lots of high altitude sled turbo tuning, and enjoys performance snowmobiling even more than he does his high-tech TIG welding business. He is a hair away from springing for a SuperFlow dyno that will allow us to see engine performance at high altitude. I would love to send things we test at sea level to Bill for 6000 ft altitude testing. He is even contemplating a portable dyno unit that he can trailer up to "Heartbreak Ridge" (named for 800cc sled owners who will cry when they see 100 observed HP readings) at 10,000 ft. What a revelation for the mountain riders, who need extra performance more than anyone!

CARB UPDATE...

I received a letter from one Boswell associate that many of you have seen faxed about recently. Joe Portale of RPG in N. Bergen, NJ, described to me a "window" of tuning that exists with the Boswell modified carburetors, where suddenly fuel becomes vaporized instead of being merely atomized. At this point, Joe claims that Boswell BSFC x 1.35 = traditional BSFC. That means, on a snowmobile race engine that makes peak sustained HP at, say, .58 lb/hphr would make peak sustained HP at .43 lb/hphr with Boswell modded carbs, with lower EGTs to boot.

I realize that nothing is impossible. But, this "window" is something that neither this nor any other dyno testing facility I've spoken with has experienced. There have been many times that we dropped fuel flow below that at which maximum power occurred, and never encountered this vapor window that Joe described.

We're all willing to learn new things, and it would be the best if someone can show us the elusive "window" by doing a demonstration here, on any engine (your engine, please). The DynoTech challenge is that I will take anyone's engine, running with 80 degree F water temp, using fresh gas and standard Mikuni carbs, and make as much HP at as low a fuel flow as any modified Mikuni carb, size for size. That's what I've seen in the past. That's the DynoTech challenge. No animosity or jealousy- I'll be the first to shake the hand of anyone who can show us max sustained torque on a snowmobile engine at .43 lb/hphr. Kevin Cameron will be the second. All four snowmobile manufacturers, who are sweating out impending emissions regulations, will be fighting to be third, checkbooks in hand. Could this be a reincarnation of the fabled 100 MPG carburetor that the oil companies mysteriously continue to quash year after year? The proof is in our dyno.

BAD THINGS...

Remember the Champion QX we tested in seasons past? (Vol 4. no. 5) They've renamed it "White Lightning". The last two times we've tried it on the dyno, on one stock and one modified engine, we lost several HP.

In the past, this diesel fuel-like additive has typically given us one percent or more power increases. It's supposed to be a supplemental lubricant, and passes all fuel techs. D&D Cycles' dragracers have used it for years. Anyone else whose exhaust has a Cummins-like aroma is probably doing the same.

These recent disappointments should be a warning that something in their formulation may have been altered.

OTHER THINGS I'VE RECENTLY THROWN AWAY

Besides the half a bottle of White Lightning discarded during a recent semi-annual spring cleaning:

(1) Fuel Magnetizer, external.

This was a red plastic coated horseshoe magnet,



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designed to fit over the fuel line feeding the engine. This device was supposed to align the fuel molecules as they entered the carbs but did nothing to alter power or BSFC. They reportedly sell 500,000 of these per year.

(2) 3/4 bottle of Energy Release.

I wanted to harm the well-meaning sales person who gave me this stuff, after it somehow permanently sucked several hard-earned HP out of the heart of my old modified Indy 650 engine. The power returned after a re-hone job, but it was an unsettling experience. Since then, I've avoided wierd lubes.

(3) two used Split-Fire spark plugs.

(4) Fuel Magnetizer, internal.

Bobby Rahal endorsed this one, which has some bimetal stuff inside a tube that the gas flows through on its way to the engine. It may have aligned the molecules, but it didn't make any power. Not a good performance value at over \$200. Someone else bought that for us.

(5) A full bottle of Slick 50 2-stroke treatment as tested in Vol. 1 no. 5.

(6) 8" x 5" chunk of Suzuki motorcycle crankcase.

A euphoric dyno customer with a nitrous injected Suzuki 1325cc drag bike wouldn't quit at 280 HP. He wanted to break Ed Sedlemeier's 350 HP record (Vol. 2 no. 6). Instead, he broke a connecting rod and sawed his engine in half at 12,000 RPM. The chunk of ribbed crankcase casting was a cool conversation piece, but it scared people away.

(7) An Injection Research Services remote mixture control rheostat.

This could have been a great thing--EFI on snowmobiles, but I believe the Injection Research guys failed to address pipe center section temperature and the necessity for shifting the fuel map sideways (see Vol. 3 no. 4). There are lots of people still running the IRS EFI systems on stock and mildly modded sleds, but there are many more on shelves.

(8) An aftermarket RXL triple pipe chip, unused.

See #7. Guys with RXLs and triple pipes generally had nightmarish problems. They hogged the Friday tech line for several years when EFI was in vogue. Gradually, though, those piped RXLs got traded in, probably toward new Ultras.

9) A set of aftermarket Indy 500 twin pipes that made eight less HP than a stock single pipe.

BACKPRESSURE

Here's another phenomenon that has been a recent subject of great discussion and debate.

As I comprehend it, it takes a combination of backpressure and soundwaves inside the two-stroke engine's tuned pipe(s) to properly "supercharge" the cylinder with air/fuel mixture as the exhaust port closes. This is the "ram" effect, or inertia of the column of air/fuel mixture as it travels through the transfer ports, swirls through the cylinder and combustion chamber, then continues on out the exhaust port into the header pipes. It proceeds some distance prior to its being packed back into the cylinder by the sound wave returning to the engine, just as the piston closes the exhaust port.

The comparatively weak sound wave, however, would be rendered less useful in a low pressure atmosphere. If there were no backpressure in the pipe, as with only a rear cone with a huge non-restrictive muffler, large volumes of air/fuel mixture would blow through the engine, and very little of that would be returned and packed back into the combustion chamber by the returning sound wave. The missing air/fuel mixture would be considered to have "short-circuited" the system. At the other extreme, too high a backpressure would result in less air/fuel mixture being blown through the exhaust port into the header pipe. Now, the same returning sound wave will cram a combination of intake charge and residual high temperature exhaust gases plus possibly a dose of those nasty "active radicals" that promote detonation (TCD Vol 6, no. 2 "Is There a Third Way?") back into the closing exhaust port.

As we saw in Vol. 5 no. 4 "Cold Facts Hot Pipes", the RPM where the engine's peak torque (maximum cylinder filling) and horsepower occur increases as the exhaust gas temperature throughout the inside of the tuned pipe gradually becomes higher. We now have a better understanding of the effects of increasing speed of sound as temperature increases and the resulting effect on peak engine operating speed.

In that article, we saw the engine's airflow and HP drop as average exhaust gas temperature increased through the pipe. At that time, I considered that totally the result of the engine building crankcase heat, and volumetric efficiency falling off as a result.

But I never considered the effects of the Ideal Gas Law (a combination of Boyle's Law and Charles' Law), which states that the absolute temperature and absolute pressure of a fixed volume of a gas is directly proportional. If you double the temperature (in degrees Kelvin) of a fixed number of molecules of any gas, its volume will double, or attempt to double. If these newly heated molecules of gas are retained in a fixed container, their absolute pressure will rise proportionately. This is the phenomenon that causes





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metric efficiency to fall off as temperature increases. It is also the phenomenon that causes internal combustion engines to run; intake air being heated by the burning fuel tries to grow to many times its original volume, and pushes the piston to the bottom of the cylinder. I never thought about the Ideal Gas Law's effect on backpressure in the tuned pipes, until our recent experiences with the new Polaris XCR 600 SP as tested in this issue.

The XCR 600 SP apparently has insufficient backpressure for max power in the 10-20 second dyno runs we typically use; lean, hot jetting and extended operation under load is required before the power "comes around". In this case, it took about 60 seconds at full throttle before maximum power was achieved. How could this be? Engines usually make the max HP in their first 20 seconds at full throttle, then tail off just a bit as volumetric efficiency is reduced by the heated crankcase, crankshaft, and cylinders.

As we observed in Kevin's pipe temperature article, the temperature at in the rear cone began the multiple pass test at a very low 820 degrees F (711 degrees K), then after 20 seconds was up to 1024 degrees F (824 degrees K). This may effectively increase backpressure because of the increased volume of hot gas trying to escape from the fixed stinger/ muffler outlet.

With these two new models, our first reaction might be that the factory goofed, and left lots of HP on the table. But, the warranty-conscious factories are asked by consumers to provide trouble-free operation for mile after mile at full throttle, with always questionable quality gasoline. Polaris feels that it must provide warranty-free operation at sea level, full throttle for four minutes, equal to about seven miles at 100 MPH. During that time, if the pipes were restrictive enough to provide optimum 1/4 to 1/2 mile full throttle runs, perhaps causing excessive heat in the intake charge returned through the exhaust port and the presence of active radicals in the mixture. How do other machines get away with providing optimal 1/4 mile acceleration without seven mile detonation? Maybe they don't. We aren't privy to the factories' warranty claims (should they really be asked to cover seven minutes at 100-120 mph?), but it may be \$ millions each season. That may be a good enough reason to sacrifice some 10-20 second HP, but isn't this excessive?

At the risk of sounding patronizing, I have to feel sorry for the snowmobile manufacturers. This is the only form of motorsports (other than understressed, over-cooled outboard marine engines and mopeds) that

must provide maximum performance PLUS guaranteed reliability for seven+ mile full throttle runs on low octane gasoline.

How about maintaining a constant backpressure by varying outlet size, or some sort of pressure bleed like turbocharger wastegates? Would this optimize engine performance for all pipe temperatures and altitudes?

Some of my DynoTech pals in Canada (the Ottawa River Rats, for example) refer to most high horsepower-producing aftermarket pipes as "grip-tubes" after the pipes' propensity for seizing pistons during multi-mile, full throttle, frozen river excursions on pump gas. I've long considered these self-inflicted seizures the result of skyrocketing engine coolant temperature combined with Quebec's and Ontario's infamously questionable pump gas. Now, however, I believe that these particular performance pipes, which provide optimal horsepower for 10-20 seconds or more, may build excessive backpressure as the temperature of the exhaust gas inside the rear-cone approaches that at the header pipe after four or five minutes at WOT.

Next time I have a stock XCR 600 SP on the dyno, I will try to measure exhaust backpressure and HP and compare to time of operation.

Two interesting bits of feedback I've received on the XCR 600 SP:

One Canadian DynoTech subscriber who restricted the stinger outlets on his XCR 600 SP was rewarded with better cold-pipe acceleration, and detonation at extended (seven mile?) WOT runs on Canadian pump gas. I wonder if Polaris Industries paid for that experiment?

Marysville, Ohio Polaris dealer Aaron Story of Story's Fun Center reports that his HTG big-bore XCR 600/800 SP, with stock 600 SP pipes and muffler, pulls hard immediately at 8500 RPM from a dead stop, then creeps up to 8600 RPM free of deto on Ohio and Michigan pump gas for 1/3 to 1/2 mile at WOT. Seven miles might be questionable, though. But, who cares? Aaron is one of the vast majority of snowmobilers who don't want to wait for their power to arrive, and do not particularly enjoy droning on mile after mile at 120 MPH waiting for a drive belt or track to shred, or a piston to eventually melt down.

If, somehow, the factories could have a computer chip in their CDI's that would recall, say, the most recent ten minutes of an engine's operation, like a commercial airliner's "black box", perhaps warranty claims for abuse could be minimized. Maybe altitude could be registered to cut slack for mountain climbers, who can safely use full throttle for minutes at a time, albeit at up to 33% lower power and lower incidence of engine problems.

1996 ZRT 600 Arctic Cat PIPE UPDATE

Weight with three gallons of gas: 548 lbs.

In our last issue, we created a great deal of excitement by Arctco, Cat dealers and ZRT600 owners over this pipe leaking issue. What at first appeared as a cosmetic problem (oily bellypans) actually was beating up the power on the dyno and, of course, acceleration and top speed in the field.

Arctco maintains (see their letter which follows) that it was a first day production glitch that was rectified on day two.

Arctco's final determination was that there was no official "bulletin" on a two hour pipe refit for ZRT600's with leaking header pipes as we had reported in Vol. 6 no. 4. Arctco's Media Relations Coordinator Paul James told me that Arctco was reimbursing dealers on "an individual basis" for fixing leaking pipes. That is fine for consumers who have had their leaking pipes remedied, but the absence of an official "bulletin" precludes pipe cutting and fitting for stock class dragracers.

While some disinterested dealers downplayed the importance of proper sealing to their customers ("drive it for a few hundred miles and it will seal itself" or "a little oil in the bellypan doesn't mean much"), many performance minded dealers have been able to satisfactorily deal with it and, as Paul James indicated, all of them have been properly remunerated by Arctco for their efforts.

This seemingly insignificant, but power-robbing malady taken care of, here's Larry Bartlett's ZRT600 once more, with 400 miles and "several" hours of intensive fitting and sealing of the pipe flanges. Now, each pipe's first circumferential header pipe weld is 92 mm from the face of each piston. For those who are fitting the pipes, it is easy to make sure that the distance from the flange to the center of the first weld is the same for each of the three pipes.

Once Larry had accomplished this task, he had to cut and reweld the muffler box mounts to allow the box to slide forward to fit the pipes. As we could see from these dyno results, the effort was rewarded with huge performance gains.

Here's the new baseline test, with the pipes fitted and

sealed properly, with the stock main jets.

1996 ZRT 600 350 MJ
Stock Pipe Fitted and Sealed
 Data for 29.92 in. Hg, 60 deg. F dry air
 Test: 100 RPM/sec Acceleration
 Fuel Specific Gravity: .744
 Vapor Pressure: .36
 Barometric Pressure: 30.23

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
6500	60.2	74.5	69.1	132.3	8.8	.91	49
6750	63.8	82.0	71.8	135.7	8.7	.86	49
7000	68.5	91.3	78.4	142.3	8.3	.84	50
7250	70.8	97.7	81.3	148.2	8.4	.82	50
7500	73.4	104.8	81.9	154.2	8.6	.77	50
7750	74.6	110.1	83.4	159.8	8.8	.74	49
8000	76.6	116.7	81.8	168.4	9.5	.69	49
8250	77.8	122.2	75.0	174.8	10.7	.60	50
8500	77.2	124.9	87.3	181.9	9.6	.69	50
8750	74.0	123.3	93.0	184.7	9.1	.74	51
9000	57.7	98.9	81.8	184.9	10.4	.81	51

1996 ZRT 600 320 MJ
Stock Pipe Fitted and Sealed
 Data for 29.92 in. Hg, 60 deg. F dry air
 Test: 100 RPM/sec Acceleration
 Fuel Specific Gravity: .744
 Vapor Pressure: .14 Barometric Pressure: 30.23

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
6750	61.4	78.3	62.7	132.3	9.7	.78	45
7000	69.3	92.4	71.8	142.9	9.1	.76	45
7250	72.2	99.7	74.0	148.2	9.2	.73	46
7500	73.6	105.1	75.2	153.4	9.4	.70	45
7750	75.4	111.3	73.3	158.8	9.9	.65	46
8000	77.3	117.7	75.4	165.3	10.1	.63	46
8250	78.8	123.8	74.4	174.3	10.8	.59	47
8500	78.5	127.0	79.3	182.4	10.6	.61	46
8750	76.6	127.6	83.9	187.2	10.2	.64	46
9000	69.2	118.6	76.4	189.9	11.4	.63	45

Now that we realized how this engine's performance benefited from preventing exhaust pressure leaks, we suspected that these aftermarket silencer manufacturers' claims of additional power might be correct. Here's a set of D&D Cycle's "Three Pack" silencers, which provide additional backpressure for the ZRT 600 engine. This provides additional horsepower for a 10-20 second dyno run, but may cause more backpressure than the engine requires during, say, a seven mile WOT run on a frozen river or lake (see FEEDBACK- "Backpressure").

**1996 ZRT600 350 MJ
Stock Pipe Fitted & Sealed
D&D 3-Pack Silencer 98dB**

Data for 29.92 in. Hg, 60 deg. F dry air
Test: 100 RPM/sec Acceleration
Fuel Specific Gravity: .744
Vapor Pressure: .36 Barometric Pressure: 30.23

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
6500	63.8	79.0	67.2	130.9	8.9	.84	49
6750	66.5	85.5	71.8	132.7	8.5	.82	49
7000	70.5	94.0	75.5	139.2	8.5	.79	50
7250	71.9	99.3	73.4	142.7	8.9	.73	50
7500	74.3	106.1	79.4	148.8	8.6	.73	49
7750	75.5	111.4	80.2	153.5	8.8	.71	49
8000	78.4	119.4	78.9	164.4	9.6	.65	49
8250	79.8	125.4	83.4	171.6	9.4	.65	49
8500	80.4	130.1	76.5	179.9	10.8	.58	50
8750	76.2	127.6	90.9	183.0	9.2	.70	50
9000	63.2	108.3	84.0	182.0	10.0	.76	50

**1996 ZRT600 350 MJ
PSI Pipes 96 dB**

Data for 29.92 in. Hg, 60 deg. F dry air
Test: 100 RPM/sec Acceleration
Fuel Specific Gravity: .744
Vapor Pressure: .36 Barometric Pressure: 30.22

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
6750	61.8	79.4	76.6	141.3	8.5	.95	52
7000	65.9	87.8	76.5	146.7	8.8	.86	53
7250	67.2	92.8	83.4	145.9	8.0	.89	54
7500	65.4	93.4	82.1	143.9	8.1	.87	54
7750	61.8	91.2	91.7	144.9	7.3	.99	53
8000	62.3	94.9	95.4	148.8	7.2	.99	53
8250	70.1	110.1	72.5	164.5	10.4	.65	52
8500	71.8	116.2	82.3	168.5	9.4	.70	54
8750	73.9	123.1	83.2	176.6	9.7	.67	53
9000	75.6	129.6	95.4	184.2	8.9	.72	51
9250	74.3	130.9	89.8	187.9	9.6	.68	51
9500	70.7	127.9	78.9	190.8	11.1	.61	50

Here's a set of PSI triple pipes installed on our stocker. For those who have first day production ZRT600's, PSI's excellent chassis fit and flange seal allow the average dealer or consumer an easy alternative to cutting and rewelding the stock pipes.

At test time, we had a set of RPC triple pipes that would have necessitated cutting the left front motor mount to clear the PTO header pipe. We'll save those for the first time we have a stock ZRT 600 engine out of the chassis on the dyno where we'll be analyzing other aftermarket pipes, reeds, and compression and cylinder mods.

To avoid any further misunderstanding as to Arctco's position regarding pipe fit on the 600 ZRT, following is the fax, printed verbatim, which was received by DYNOTECH, from the desk of Paul James, Media Relations Coordinator for Arctco, and dated Dec. 12, 1995.

"Jim, as we discussed, this is what you should print to correct your error announcing a two hour pipe fitting warranty across the board on ZRT 600s in the last issue of Dynotech.

There is no service bulletin or program regarding pipe fit on ZRT 600s.

"There may be only a few early production ZRT 600 models that require attention, as exhaust headers were improved after the first day of production" said Arctco Service Manager Dean Lawrenz. "If there are any questions, Arctco dealers should contact their service representative for their area."

Jim, failure to print this correction in your next issue may force Arctco to take legal action."

Living With Detonation

**Kevin
Cameron
The Cellar Dweller**

Detonation sets the final limits on spark-ignition engine performance. Raise the compression high enough, advance the spark far enough, turn the boost up enough, or let fuel quality fall enough, and you begin your relationship with detonation.

Most of these detonation-provoking variables just happen to be major performance variables as well. Therefore, as you push performance upward by the usual techniques, detonation is waiting to greet you with its warning tinkle and the ominous rise in engine temperature that we all know so well. Pushing the performance variables further just makes the detonation

worse until the result is widespread destruction of engine parts - piston dome oil-canning, piston and cylinder head erosion, seizure, and even outright piston break-up.

Tuners who want maximum power have to become close neighbors with deto, to understand its habits and little quirks, to know how to tip-toe around the very edge of the monster without awakening it. There's nothing quite so frustrating and humbling as to see a winning rival's pistons come out during teardown, shiny and perfect, barely broken-in, while your own less powerful engine is junk with long black streaks on its

Living With Detonation continued

seized pistons. What does he know that you don't ?

Detonation is abnormal, explosive combustion of some of the "end-gas", or last parts of the charge to burn - typically somewhere out in the squish band. It occurs after normal ignition and combustion of most of the charge, so it is not to be confused with pre-ignition, which is self-ignition of the charge before passage of the ignition spark. Detonation is caused by heat-driven, time-dependent chemical changes in the compressed and heated unburned fuel-air mixture. These changes convert it from a smooth-burning substance with a flame speed of at most a few hundred feet per second, into a violent explosive, capable of self-igniting into a blast wave moving at the local speed of sound - several thousand feet per second.

The high-frequency tinkling sound or squeak you hear (if you are fortunate enough to get any warning at all) is characteristic of this high speed wave, reverberating across the diameter of your cylinders. The overheating that results from even light detonation is caused by the damage that the shock wave does to the insulating layer of stagnant gas that usually clings to the interior surfaces of the combustion chamber. Gases are excellent insulators, but when even this thin layer is stirred into the hot gas in the chamber, heat transfer from combustion gas to metal parts is strongly accelerated. If your engine detonates on an instrumented dyno, you will see a fall in exhaust-gas temperature. This surprises many people, who naturally expect anything that causes seizure to create more heat, not less. However, what is really happening is that heat is simply re-routed; some heat that had been going out in exhaust gas is now being instead transmitted into the piston and cylinder head. Coolant temperature rises; exhaust gas temperature falls. The overtemperated piston swells and seizes.

I like to think of what goes on inside the detonating engine as being like a fight breaking out in a crowded, smoky bar room. The fuel molecules are the rowdy lads who have come, not for the fellowship, but in hope of a fight. If you make the barroom smaller (raise the compression ratio, thereby making the clearance volume smaller), all those big, bad-tempered guys are packed in closer together. The longer you leave them like this, packed tightly together, the more certain it becomes that a fight will start. This equates to too-early ignition timing, which holds the fuel-air mixture longer at high pressure and temperature - or to lugging an engine, which does the same thing. When someone's temper does flare in that small barroom, the fight spreads

quickly. As one lad draws back his arm to punch his neighbor, his elbow hits another in the mouth, and he in turn hits whoever is nearest. This equates to the increase in flame speed that occurs when fuel and air molecules are crowded closer together.

Flame speed will increase if; (1) you raise compression ratio (make the barroom smaller) or; (2) you pack more mixture into the engine through supercharging, improved porting, etc. (letting too many people into the bar), or; (3) you increase charge purity. This can result from a better pipe or improved transfer aiming, which chase out exhaust better and retain a higher percentage of fresh charge, with less exhaust residual gas (change the clientele of your bar, attracting more rowdies, discouraging the bland family men), or: (4) you raise the temperature of the charge in any way (make 'em mad, turn up the music), or: (5) you increase turbulence with tighter or wider squish (I'm running out of analogies - sorry)

When any of these kinds of changes are made, flame speed will increase. As a result, combustion will reach peak pressure before the crank is ready to pull the piston down. This will encourage detonation by holding the charge at high pressure and temperature longer. For this reason, any time you raise compression, improve scavenging, or do any of the other things on the above list, you must again find the optimum timing for peak power. Different engines require different ignition timings, but peak pressure has to occur at around 14-15 degrees ATDC to generate peak power. If your combustion is a little slow, you may have to fire at 18-20 deg. BTDC to achieve this. If you run tight squish, down near the mechanical limit, you may have very rapid combustion, and need only something like 10 deg. BTDC or even less. But in both cases, peak pressure is occurring at the same place - about 14-15 deg. ATDC. Never fail to re-evaluate ignition timing after engine modification of any kind - including different gasoline.

A clear demonstration of flame-speed effects can be seen in today's mapped ignition curves. Where formerly, engines had either fixed ignition timing, or a simple retard curve, today's computer-stored ignition curves are really upside-down maps of flame speed. Wherever the engine's torque is high, ignition lead will tend to be smaller, for high torque means high flame speed. And wherever the pipe and engine set-up create a torque dip or flat-spot, ignition lead will be larger, for low torque means poorer cylinder-filling, a slower rate of burning, and therefore a need for earlier ignition to deliver peak pressure at the right point. Mapped ignitions are wonderful because they truly tip-toe around the edges of detonation. Without a mapped ignition, you had to set your timing for the requirements at peak torque, and if it needed more or less timing at some other RPM, too bad. Mapped ignitions, since they deliver best timing at all revs, make an engine much livelier in acceleration.



Living With Detonation **continued**

But the downside is that, if you modify your engine with different pipes and porting, the mountains and valleys of your ignition map may no longer match the landscape of your new torque curve. Instead of tip-toeing around the edges of detonation, you are mashing its toes and making it tinkle and squeak. This is why an addressable ignition (one whose curve can be changed or replaced from a computer keyboard) is now becoming an important tuning tool. There are three major tools for fighting detonation. One is to accelerate combustion enough to finish the process before the chemical changes that lead to deto can mature. This is why we add turbulence to combustion by the use of compression squish. By making the squish band wider (occupying more of the piston's area) and/or thinner (closer approach of the piston to the squish area), we can speed up the charge-stirring jets that squish produces - and thereby speed up combustion.

The second is, or course, the use of knock-resistant fuels, and the third is to do anything that will reduce the temperature of the fuel-air charge at the moment of ignition. This is affected by intake air temperature, by engine coolant temperature, by the quality of piston cooling, and so on. It is a little-known fact that, as an engine reaches higher rpm, it becomes naturally more resistant to detonation. Honda found that engines running above 12,000 rpm could operate knock-free on progressively lower-octane fuels. The reason? Knock is a time-dependent phenomenon; if you don't give it time to develop, it won't develop. And making combustion time shorter by increasing flame speed is another way to the same goal.

Too many tuners, even today, associate more spark lead with better performance. Even the words used carry hidden meaning; would you rather be considered advanced, or retarded? But the fact is that shorter combustion times work to suppress detonation. Building more turbulence into your engine can speed up flame travel, allowing you to develop as much or more power, but with retarded ignition timing. By speeding up combustion and being able to make best power with retarded timing, you win the race against detonation.

The trick is to find the "sweet spot", the ideal combination of compression ratio and turbulence that will operate knock-free at high horsepower. Too little turbulence and flame speed sags, and to get best power, you have to run such early timing that detonation has time to develop. Too much

turbulence and flame speed rises so high that ignition gives your engine a violent thump that's too much for the crankshaft.

The generation of turbulence from squish is itself a similar search for a sweet spot. Recent pure-racing cylinder head designs pursue a simplified goal. Because the charge forced into the piston-ring crevice and squish band cannot burn completely, it's best to minimize these volumes. Piston rings are located as near the top of the piston as temperature will allow; too close, and they stick in their grooves in carbonized oil. Squish volume is minimized by reducing the vertical clearance to the mechanical limit (as close as it can be and still not have piston-to-head contact at high revs). Then the only task is to find the squish band width that provides enough turbulence to give knock-free operation at the desired compression ratio (provided it is not unrealistically high!).

But it's tempting to vary compression ratio by simply cutting the cylinder head gasket surface more or less. This varies not only the compression ratio, but the turbulence; a big cut raises compression a lot and thins the squish band. There is no guarantee that squish turbulence will be right for that compression ratio. Therefore development must proceed on the basis of preparing heads with squish vertical clearance at the mechanical limit, but with different squish band widths - and all with the same compression ratio. Once the best squish width and ignition timing are found in this way, you can move up to a higher ratio to see if some new combination can also be made to run knock-free. The work proceeds (no one said it would be easy or cheap) until you have found the highest compression ratio that will work with some possible squish arrangement. Pushing performance to the limits imposed by detonation is rewarding because then you can be the one with the beautiful, shiny, unmarked pistons, kissing the trophy girl. And others, with less power and more problems, can contemplate their seizures.

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