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1997 Arctic Cat 600ZRT

PIPE SHOOTOUT #33

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Aaen Performance	*(414-552-8981)*
Black Magic Motorsports	*(218-681-1150)*
D&D Cycles	*(315-376-8013)*
Nelson Speed Shop	*(616-754-9185)*
Reichard Performance	*(414-251-8472)*

This ZRT 600 is the same 1996 engine tested in Vol. 6, no.5 and Vol. 6 no. 6. 1500 trail miles have been logged to date, and it has now made about 200 dyno passes to boot. The 1997 pipes are brand new, removed from Larry's wife's new ZRT600 purchased from nearby Norton Enterprises in E. Bethany, NY.

After Larry had cut and fit his 1996 pipes last year, he achieved maximum performance by clutching for an average 8500 RPM. Midsummer teardown showed that piston skirt clearance had grown to .0085". The original pistons were re-ringed, and the resulting dyno sheets show that, compared to when it was new, power levels were largely unaffected by the large clearances.

For this test, the engine was removed from the chassis and bolted to our dyno engine plate. The stock airbox was used, with baffles in place, but plastic inlet screens removed. While the screens are probably good to prevent debris from entering the airbox, it does in fact impede airflow a bit, maybe a horsepower's worth or so. Dyno testing on this engine has shown maximum airflow and power with the screens removed and the cylindrical baffles left in place. 40-1 premixed 93 octane gasoline was used, and in each situation, we attempted to obtain reasonably equal A/F ratios and BSFC. During the test session, there were several instances where jetting was inadvertantly reduced to a level leaner than maximum power, but detonation was never experienced.

Several aftermarket pipe sets utilize the stock '96 exhaust flanges. Aaen, Reichard, and Black Magic pipes used these flanges, and were more difficult to seal. We took great care to ensure that exhaust flange leakage was kept to a minimum by double springing and visual observation during each run. The 1997 stock flanges are a great improvement, with tapered donut seals very much like the smaller donut seals at the cannister connections. D&D and Nelson pipes utilize the 1997 flanges. PSI pipes use their own double ring seal flanges.

Larry's perfectly fitted 1996 pipes made a bit more horsepower than the new '97 pipes. Though they appear identical except for the new flanges, close visual inspection reveals a slight difference in the middle pipe; the rear cone on the '97 middle pipe appears longer with a more gradual taper. Could this be the difference? Or, is the slightly increased I.D. of the '97 flanges the culprit? As we've seen over the past ten years, higher velocity, smaller I.D. exhaust ports, flanges and header pipes have become fashionable. The '97 header pipes appeared longer, so we cut two MM from the gasket sealing surface of a set of '97 flanges, resulting in a slight loss in power.

For 15 second full throttle dyno runs, the stock pipes and cannister are not restrictive enough to maximize horsepower. Usually three 15 second acceleration pulls on the dyno, to build heat in the stock pipes to reduce the airflow and to increase backpressure were necessary to make the horsepower shown here. This may be a disadvantage for trailriders and dragracers who desire maximum "warm pipe" acceleration, and don't care to wait for the big power to arrive. Hillclimbers and lake and river runners, however, who take delight in maintaining full throttle for minutes at a time will enjoy the advantage of maximum power and detonation resistance provided by a a more free flowing exhaust.

The point is, airflow and time to maximum power is an important consideration in selecting an exhaust system. For example, the D&D (and possibly other) aftermarket silencers fitted to the stock pipes make additional power on our 15 second acceleration tests. If, however, we hold the engine at full throttle for a minute or more we would very likely see power diminished, compared to stock, because the hot pipes' airflow become too low to work properly. In those situations, it is likey that instead of primarily cool fresh intake charge being packed back into the exhaust port and cylinder by the returning sound wave, hot exhaust gases, devoid of fresh fuel and oxygen but instead loaded with detonation-producing active radicals get mixed in with the good stuff in the cylinder.

To generalize, "tight" pipes often make quick power, good for dragging and most trail riding. But if your desire is full throttle periods measured in fractions of an hour, higher airflow is usually better. How about a backpressure, time, or pipe temperature controlled exhaust bleed-valve or waste gate? It seems as though something could be concocted that would give an engine optimum backpressure at all times. For now, everyone must use their best judgement to select one or the other, or something in between, that best suits our needs.

Occasionally, we'll see a pipe/silencer combo that makes the highest power at the highest airflow. That would very likely represent an ideal selection for all intended applications.

PLEASE NOTE THAT THESE JET SPECS PROVIDED MAXIMUM SAFE PUMP GAS POWER AT THE CARB AIR TEMPERATURES SHOWN AS "CAT" ON EACH PRINTOUT, WITH NO CORRECTION MADE FOR HIGH VEHICLE SPEED ENRICHENING DUE TO FLOAT BOWL VENTING IN THE HIGH PRESSURE UNDERHOOD AREA (see The Effects of Underhood Pressure in Vol.4 no.4!!!)

The stock 1997 ZRT600 pipes, with stock cannister muffler made 119 CBHP at 8000 RPM on the first 15 second dyno pull. By run three, the following data resulted:

1997 ARCTIC CAT ZRT600
1997 STOCK PIPES 350 MJ 90dB
Data for 29.92 Inches Hg. 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .746
Vapor Pressure: .18
Barometer: 30.04

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
6750	68.4	87.9	71.2	166.5	10.7	.80	45
7000	70.6	94.1	72.4	171.0	10.8	.76	45
7250	73.5	101.5	75.7	177.2	10.7	.73	45
7500	75.1	107.2	74.8	182.0	11.2	.69	44
7750	77.5	114.4	80.8	185.0	10.5	.70	44
8000	78.6	119.7	83.5	191.0	10.5	.69	44
8250	78.3	123.0	82.9	194.5	10.8	.66	43
8500	76.2	123.3	84.4	196.7	10.7	.67	43
8750	68.9	114.8	87.6	198.0	10.4	.75	45

Fitting a set of D&D triple glasspack silencers gave us a 126 CBHP reading at 8250 RPM on the first 15 second dyno run, a seven HP increase over the stock can in the same time frame. Repeating the dyno runs three times gave us the following data:

1997 ARCTIC CAT ZRT600
1997 STOCK PIPES 350 MJ
D&D 3 PACK SILENCER 96 dB
Data for 29.92 Inches Hg. 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .746
Vapor Pressure: .18
Barometer: 30.05

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
6750	67.2	86.4	68.4	165.1	11.1	.78	45
7000	69.9	93.2	69.9	169.6	11.1	.74	44
7250	72.5	100.1	74.0	173.0	10.7	.73	44
7500	73.6	105.1	74.9	175.6	10.8	.70	44
7750	76.2	112.4	77.7	181.1	10.7	.68	44
8000	79.0	120.3	80.2	185.7	10.6	.66	45
8250	79.9	125.5	84.6	191.5	10.4	.66	45
8500	79.4	128.5	82.3	195.4	10.9	.63	44
8750	73.6	122.6	85.1	197.1	10.6	.68	44

We installed a set of '97 flanges that had two MM removed from the sealing surfaces, resulting in the following third pull test data that showed a slight reduction in torque and horsepower:

1997 Arctic Cat 600ZRT

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1997 ARCTIC CAT ZRT600
1997 STOCK PIPES -.100 FLANGES
D&D 3 PACK SILENCER 350 MJ

Data for 29.92 Inches Hg. 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .746
Vapor Pressure: .18
Barometer: 30.04

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
6750	65.7	84.4	58.8	160.3	12.5	.69	46
7000	68.9	91.8	63.4	167.9	12.2	.68	45
7250	71.1	98.1	78.4	172.0	11.5	.69	44
7500	72.9	104.1	73.9	175.7	10.9	.70	44
7750	75.1	110.8	78.4	177.0	10.4	.70	44
8000	76.8	117.0	78.1	182.8	10.7	.66	44
8250	78.6	123.5	80.9	187.0	10.6	.65	46
8500	79.0	127.9	81.0	191.9	10.9	.63	46
8750	74.9	124.8	85.3	194.5	10.5	.67	45

Larry's correctly fitted 1996 pipes and stock can were installed, and made 123 CBHP at 8250 RPM on the first 15 second dyno pull. Run three gave us this optimum test data:

1997 ARCTIC CAT ZRT600
1996 STOCK PIPES & CANNISTER
350 mj 90dB

Data for 29.92 Inches Hg. 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .746
Vapor Pressure: .18
Barometer: 30.03

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
6750	67.0	86.1	60.4	163.1	12.4	.69	44
7000	70.5	94.0	65.7	169.6	11.9	.69	44
7250	73.4	101.3	72.7	175.8	11.1	.71	45
7500	75.7	108.1	76.5	179.2	10.8	.70	44
7750	77.5	114.4	77.7	184.3	10.9	.67	44
8000	79.4	120.9	81.4	187.9	10.6	.66	44
8250	79.7	125.2	82.8	191.6	10.6	.65	44
8500	79.0	127.9	83.3	195.8	10.8	.64	44
8750	64.9	124.8	84.1	198.1	10.8	.66	44

We installed the D&D three-pack silencer on Larry's '96 pipes, and on the first pull the ZRT 600 made 126 CBHP at 8250 RPM, a three HP increase. The third pull netted 129 HP @8500, slightly diminished from the following second pull data:

1997 ARCTIC CAT ZRT 600
1996 STOCK PIPES 350 MJ
D&D 3 PACK SILENCER 96 dB

Data for 29.92 Inches Hg. 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .746
Vapor Pressure: .18
Barometer: 30.09

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
6750	69.5	89.3	63.1	166.4	12.1	.70	48
7000	71.1	94.8	66.8	168.7	11.6	.70	48
7250	74.0	102.2	74.0	174.3	10.8	.71	48
7500	76.4	109.1	79.8	177.2	10.2	.72	48
7750	78.2	115.4	80.4	183.8	10.5	.69	48
8000	80.3	122.3	79.3	188.3	10.9	.64	48
8250	81.3	127.7	82.7	194.2	10.8	.64	48
8500	80.6	130.4	84.4	196.9	10.7	.64	48
8750	74.9	124.8	86.6	196.7	10.4	.69	49
9000	57.1	97.8	91.2	191.1	9.6	.92	48

While the 96 flanges were installed, we fitted a set of Aaen triple pipes. During the dyno testing with these pipes, we noted a slight bit of exhaust leakage at each of the three narrow '96 flanges. The second dyno pull revealed an insignificant .3 CBHP drop at 9250 RPM. This is the first dyno run results:

1997 ARCTIC CAT ZRT600
AAEN TRIPLE PIPES 350 MJ 96dB

Data for 29.92 Inches Hg. 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .746
Vapor Pressure: .18
Barometer: 30.10

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
6750	60.9	78.3	66.6	157.5	10.9	.83	43
7000	64.1	85.4	67.8	161.4	10.9	.78	44
7250	65.5	90.4	71.1	164.7	10.6	.77	45
7500	66.2	94.5	71.9	165.0	10.5	.75	44
7750	67.3	99.3	74.6	165.6	10.2	.74	43
8000	68.1	103.7	72.3	166.5	10.6	.68	44
8250	68.4	107.4	75.6	168.2	10.2	.69	44
8500	70.6	114.3	76.5	173.8	10.4	.66	45
8750	71.8	119.6	77.8	180.0	10.6	.64	44
9000	73.4	125.8	79.7	187.9	10.8	.62	45
9250	72.3	127.3	79.8	191.0	11.0	.62	45
9500	66.0	119.4	80.2	190.7	10.9	.66	45

Reichard triple pipes also utilized the '96 flanges, and fitting and sealing were a bit better than Aaen's due to closer header pipe tolerances. Like the Aaen pipes, the second pull resulted in a less than 1% drop in power to 128.2 HP with the peak sliding up to 9000 RPM.

1997 ARCTIC CAT ZRT600
REICHARD TRIPLE 350 M J PIPES 96dB

Data for 29.92 Inches Hg. 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .746
Vapor Pressure: .18 Barometer: 30.08

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
6750	65.2	83.8	59.2	164.4	12.8	.69	43
7000	67.3	89.7	66.0	168.2	11.7	.72	43
7250	69.3	95.7	71.7	172.0	11.0	.74	43
7500	71.4	102.4	74.0	172.8	10.8	.71	43
7750	72.2	106.5	76.7	174.1	10.4	.71	43
8000	73.6	112.1	73.1	176.9	10.5	.68	43
8250	74.8	117.5	78.9	182.7	10.6	.66	44
8500	76.9	124.5	80.4	190.5	10.9	.64	44
8750	77.6	129.3	82.8	195.9	10.9	.63	44
9000	73.5	126.0	83.8	196.9	10.8	.65	45
9250	58.6	103.2	83.3	192.3	10.6	.79	44

The Black Magic triple pipes we had to test utilize the stock '96 flanges and the stock cannister silencer as well. These pipes achieved the max power shown in this data on the first pull, and lost less than one horsepower as the power peak slid up to 9500 RPM on the second. Also, these pipes needed one size larger main jet to maintain maximum HP at a low .60's BSFC.

While the data is not shown here, the D&D silencers were installed and the power dropped by one CBHP as the power peak slid up 100-200 RPM and airflow dropped to 194 SCFM. The significance of this lies in the fact that, though they utilize the stock cannister silencer, the Black Magic pipes have backpressure optimized by stinger size for quick power delivery. Consequently, unlike the stock pipe set, additional backpressure does not benefit them even in short runs. If Black Magic offers a replacement glasspack set that fits these pipes, it could be assumed that any performance gain would result from the weight saving alone.

1997 ARCTIC CAT ZRT600
BLACK MAGIC TRIPLE PIPES 350 MJ 94 dB

Data for 29.92 Inches Hg. 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .746
Vapor Pressure: .18 Barometer: 30.06

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
7000	56.7	75.6	64.9	155.1	11.0	.85	47
7250	60.5	83.5	68.2	159.5	10.7	.81	47
7500	68.6	98.0	75.2	171.9	10.5	.76	46
7750	69.6	102.7	78.4	175.5	10.3	.75	46
8000	71.6	109.1	75.8	178.7	10.8	.69	47
8250	72.0	113.1	78.7	177.8	10.4	.69	47
8500	72.2	116.9	79.7	178.7	10.3	.67	47
8750	72.5	120.8	81.1	181.7	10.3	.66	47
9000	72.7	124.6	84.1	183.8	10.0	.67	47
9250	75.2	132.4	81.2	191.8	10.8	.61	47
9500	71.9	130.1	81.9	198.9	11.2	.62	46
9750	65.2	121.0	84.0	202.2	11.1	.68	46

PSI triple pipes use their own double ring seal flanges. They also seemed happy doing repetitive runs, varying less than one HP on three pulls. The first pull gave us 132+ CBHP at 9000-9250, then the power peak slid up to 9250 on the second pull, where the folowing data was recorded. On a third successive run, the power dropped only to 132 at 9250. As a side note, even though the PSI fuel data appears higher than the other pipes tested, dropping one size to 350 main jets resulted in a slight power reduction.

1997 ARCTIC CAT ZRT600
PSI TRIPLE PIPES 360 MJ 96dB

Data for 29.92 Inches Hg. 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .746
Vapor Pressure: .18
Barometer: 30.06

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
7000	67.2	89.6	67.6	173.9	11.8	.75	49
7250	68.5	94.6	71.0	177.3	11.5	.74	48
7500	70.2	100.2	75.5	179.5	10.9	.74	47
7750	71.2	105.1	79.5	180.6	10.4	.75	47
8000	71.2	108.5	82.3	180.4	10.1	.75	48
8250	71.0	111.5	81.9	179.4	10.1	.73	48
8500	71.8	116.2	82.5	180.9	10.2	.69	48
8750	74.8	124.6	83.8	186.9	10.2	.66	48
9000	76.2	130.6	85.9	193.4	10.3	.65	48
9250	75.5	133.3	86.2	200.9	10.7	.64	47
9500	79.3	125.4	86.0	204.0	10.9	.68	47

Nelson Performance is an old and respected name in snowmobile hotrodding, but a new name in performance exhaust systems. Jack Nelson was anxious to be involved in this test session, and sent us their new ZRT 600 pipes that used the stock 1997 flanges and stock cannister muffler. With these pipes, maximum sustained power was achieved with 370 main jets. These pipes exhibited consistant power levels, varying less than 1/2 HP over the three repetitive dyno pulls. The second run printed here was the best, but both the first and third gave us 129.8 CBHP at 9750. When we informed Nelson of the results, he was suprised to see the peak power at 9750. Original design pipes were for a lower power peak, and these would appear to lend themselves better to a ported or modified engine. As a side note, with an ultra-short stroke engine like this, 9750 gives us piston speed equivalent to an XCR 600 SP running at about 8500 RPM.

1997 ARCTIC CAT ZRT600 #31
NELSON TRIPLE PIPES 370 MJ 90dB

Data for 29.92 Inches Hg. 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .746
Vapor Pressure: .18 Barometer: 30.06

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
7000	62.1	82.8	67.9	158.6	10.7	.81	52
7250	63.6	87.8	70.1	161.2	10.6	.79	51
7500	64.7	92.4	72.2	163.1	10.4	.77	51
7750	65.2	96.2	76.6	163.7	9.8	.79	51
8000	65.4	99.6	76.6	164.1	9.8	.76	50
8250	65.8	103.4	76.8	163.7	9.8	.74	51
8500	66.6	107.8	77.8	164.2	9.7	.72	53
8750	66.9	111.5	77.6	166.2	9.7	.69	52
9000	67.9	116.4	77.8	169.4	10.0	.66	52
9250	70.1	123.5	79.7	177.2	10.2	.64	51
9500	71.0	128.4	81.0	183.4	10.4	.63	52
9750	70.2	130.3	85.5	187.4	10.1	.65	52
10000	67.7	128.9	77.6	191.1	11.3	.60	51

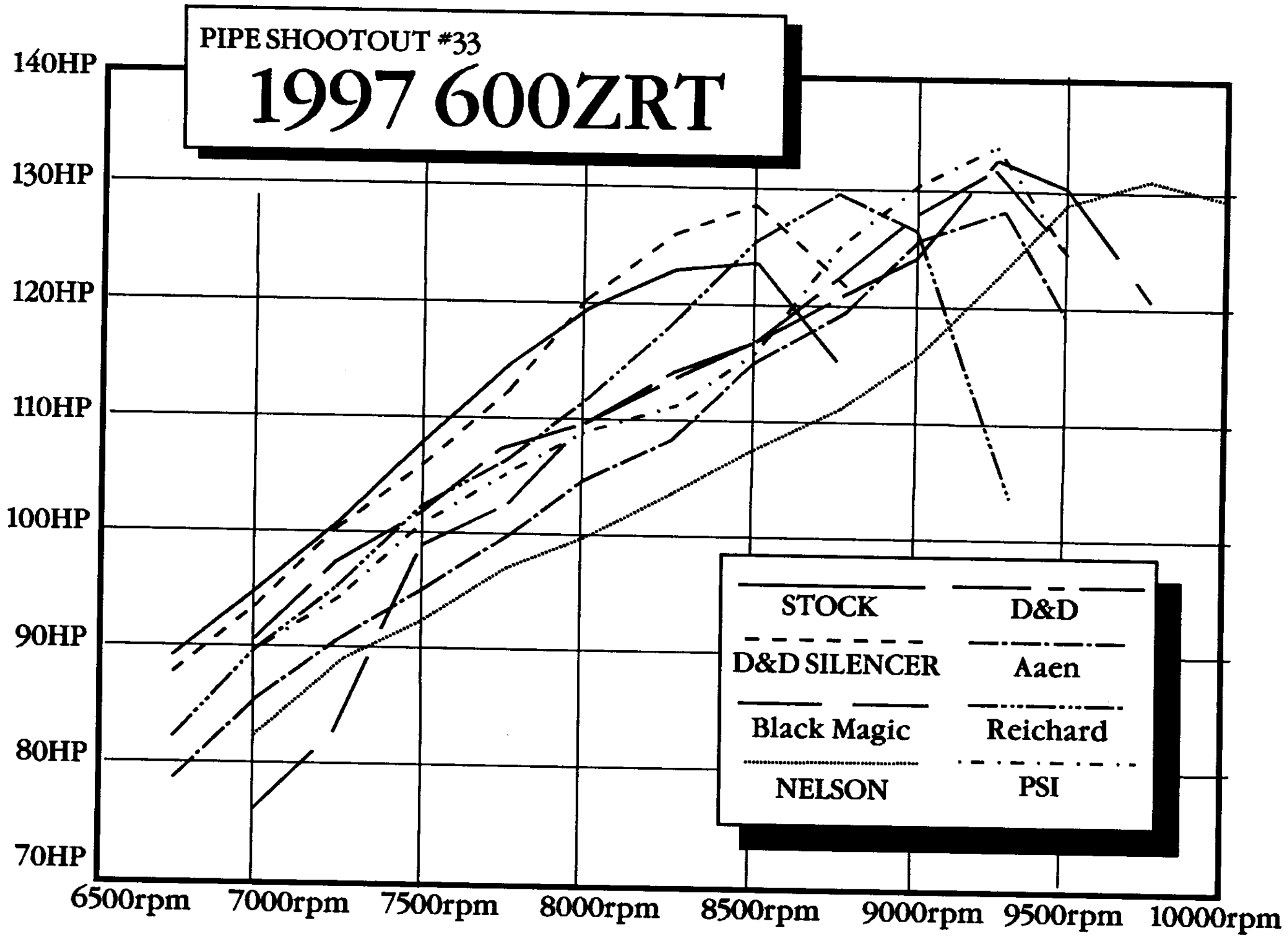
D&D Cycles triple pipes also use the stock 1997 flanges and their own triple glass-pack silencer set (arranged in a triangle fashion to exit out the stock bellypan opening). These made maximum sustained power with 360 main jets; 130.5 CBHP on the first pull, and 130.5 CBHP on the third, all at 9250 RPM. The best power came on the second run as follows:

1997 ARCTIC CAT ZRT600
D&D TRIPLE PIPES--360 MJ--98 dB

Data for 29.92 Inches Hg. 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .746
Vapor Pressure: .18
Barometer: 30.05

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
7000	68.7	91.6	66.3	168.3	11.7	.71	43
7250	70.1	96.8	69.5	171.0	11.3	.71	43
7500	71.4	102.0	72.6	172.8	10.9	.70	42
7750	72.5	107.0	74.3	172.9	10.7	.68	43
8000	72.1	109.8	77.4	172.1	10.2	.69	42
8250	72.3	113.6	78.1	171.1	10.1	.68	43
8500	72.0	116.5	79.3	171.4	9.9	.67	43
8750	73.9	123.1	79.8	176.9	10.2	.64	43
9000	74.7	128.0	79.9	186.1	10.7	.61	42
9250	74.8	131.7	82.8	197.7	11.0	.62	44
9500	69.3	125.4	85.3	200.5	10.8	.67	44

To properly conclude our pipe evaluation, we reinstalled our 1997 pipes and cannister muffler on the engine along with the original 350 main jets to verify that the engine still was in the same condition as when we began the test. The resulting data was identical to our original baseline data.



1997 ski doo 700 MACH I

By Kevin Freeman
Also Present During Test: Eric Vreeland, Jon Ranney, John Desjardins

Since Ski Doo introduced the Mach I model in 1989, there has always been a twin-cylinder rotary-valved Rotax engine under the hood. Eight model years later, the name Mach I continues, but beats with the heart of a three-banger; the new 699 type Rotax engine.

The new reed-valve inducted engine is in some respects a marriage of last years two Rotax triples found in the Formula III and Mach Z. Borrowing the bore size from the 96 Mach Z and increasing it only slightly (by .3mm) while keeping the Formula III's 61 mm stroke gives us the new middleweight engine, which is destined to keep the new Mach I very competitive with the other manufacturers this season. An improved water circulation system and Nickasil cylinders; both borrowed from the 599 type motor, will improve heat transfer away form the cylinders and increase power potential.

Taking the factory installed main jets out and referring to the Mikuni slide rule, we installed 320 main jets to match our mid-50 degree air temperature. This resulted in a mid-seventies brake specific fuel consumption and 137 CBHP at 8500 RPM.

STOCK 1997 MACH I 700 320 MJ

Data for 29.92 Inches Hg. 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .750
Vapor Pressure: .36 Barometer: 29.87

RPM	CBT	CBHP	FUEL	BSFC	CAT
5000	50.3	48.5	48.3	1.01	56
5250	54.3	54.3	47.4	.88	55
5500	60.0	62.8	47.4	.76	56
5750	65.0	71.2	53.1	.75	55
6000	71.0	81.1	59.0	.74	57
6250	75.7	90.1	61.7	.69	57
6500	80.2	99.3	69.6	.71	56
6750	82.5	106.0	75.6	.72	57
7000	84.7	112.9	84.1	.75	56
7250	86.6	119.5	85.0	.72	56
7500	86.4	123.4	97.2	.80	56
7750	85.4	126.0	99.2	.80	56
8000	85.9	130.8	101.7	.79	56
8250	86.0	135.1	97.9	.73	56
8500	84.8	137.2	101.0	.74	57
8750	72.1	120.1	96.6	.81	56

With certain areas of North America experiencing fuels laced with MTBE and possibly other oxygen bearing substances, it would appear that Rotax and Ski Doo have provided extremely safe jetting for wide open throttle (WOT) extended runs. For those of you who watch your WOT run time, monitor your fuel quality, (i.e. make sure it's really premium 93 octane fuel) and are likely to jet down a couple sizes, we ran the following test with the 290's installed. This lowered our BSFC into the high sixties. As you can see from the results shown below, the Rotax 699 was knocking on the door of 140 CBHP. This sled will definitely "have some smoke" this winter.

STOCK 1997 MACH I 700 290 MJ

Data for 29.92 Inches Hg. 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .750
Vapor Pressure: .36 Barometer: 29.88

RPM	CBT	CBHP	FUEL	BSFC	CAT
5000	49.9	47.5	42.9	.91	56
5250	53.1	53.1	42.7	.81	56
5500	59.5	62.3	49.1	.80	57
5750	62.2	68.1	51.7	.77	57
6000	68.5	78.3	54.8	.71	57
6250	72.2	85.9	58.1	.68	56
6500	77.7	86.2	64.4	.68	56
6750	82.4	105.9	72.5	.69	56
7000	85.0	113.3	79.4	.71	55
7250	87.0	120.1	88.6	.75	56
7500	87.0	124.2	84.5	.69	58
7750	85.8	126.6	89.6	.72	57
8000	85.7	130.5	91.9	.71	57
8250	86.6	136.0	92.5	.69	56
8500	86.3	139.7	92.5	.67	55
8750	76.6	127.6	88.8	.70	57

Kevin Freeman owns The Sled Shop, a Ski Doo dealership in Presque Isle, Maine. This is Kevin's sixth annual, 1600+ mile, 26 hour trip to the C&H Dyno Service to test customers' engines.

→

1997 ski doo 700 MACH I RACE IMPROVED

Heres a factory hot rod drag race engine brought in for tuning by a Ski Doo sponsored drag racer.

The engines ports are relatively unchanged, just smoothed and contoured with a spacer under the cylinder to increase port timing. The compression ratio measures 15.6 to 1 uncorrected, with a squish clearance of .043". Carbs were bored to 39.2 mm, with 370 main jets delivering maximum race gas horsepower for 10 seconds.

700 CC ROTAX IMPROVED FACTORY PIPES

Data for 29.92 Inches Hg. 60 F dry air
Test: 200 RPM/Sec Acceleration
Fuel Specific Gravity: .720
Vapor Pressure: .32
Barometer: 30.28

RPM	CBT	CBHP	FUEL	BSFC	CAT
7000	78.6	104.8	66.1	.64	66
7250	79.4	109.6	71.8	.67	66
7500	81.8	116.8	70.6	.61	64
7750	84.3	124.4	76.9	.63	64
8000	88.0	134.0	77.0	.58	65
8250	91.0	142.9	80.1	.57	65
8500	92.5	149.7	82.9	.56	65
8750	93.8	156.3	86.1	.56	64
9000	97.7	167.4	84.7	.51	65
9250	98.0	172.6	89.3	.53	64
9500	95.9	173.5	98.6	.58	64
9750	83.5	155.0	97.9	.64	63

yamaha 700 SX

Stock & Bender Power Pack Silencer Evaluation

Claiming to be the lightest 700cc triple engine, the modern new die-cast Yamaha engine has case reed induction, 33mm flatslide carbs, digital ignition, and ultra-conservative, even tiny, transfer and exhaust ports. The term "ultra-conservative" may be even more appropriate, considering the warranty difficulties that Polaris had last season with the Ultra 680. Yamaha loyalists who read only Yamaha stuff in DynoTech should go back to the past two issues to learn about the detonation problems resulting from the application of most aftermarket triple pipes to the potentially fabulously powerful 1996 Polaris Ultra 680 engine. Add excellent aftermarket pipes, 145-150 horsepower, too high a BMEP, and detonation on low octane gas became a severe problem.

Polaris' reward for selling consumers this great engine was undoubtedly record warranty claims! It is certain that the majority of the thousands of deto-wrecked pistons and scored stock cylinders were replaced at Polaris' expense, to the probable tune of of millions of dollars.

Yamaha engineers certainly have the ability to deliver competitive two-stroke power. For example, their 250cc case reed motorcycle roadracing twin makes nearly 100 CBHP (on our dyno) at the output shaft. But there, engines are run on race gas, and there are no "warranty" claims allowed for detonation. You need 100HP to be competitive, so you take your chances and buy your own spare pistons and cylinders.

So, why did the Yamaha engineers skimp on the porting of the 700SX? It should be obvious. The tiny ports are fine for delivering great low end and midrange power, and 110-115 CBHP with the best-ever single pipe on a triple. These tiny ports, however, will not flow enough air to deliver Ultra power with aftermarket pipes, unless the cylinders are radically carved out and opened up, which will void the warranty. I would suspect that the wheezing cylinders will make, at best, 130-135 CBHP at reasonable engine speeds with the addition of good triple pipes. That should minimize the likelyhood of Ultra-like warranty expenses. And, 135 CBHP is not bad, considering the light weight of the sled. But, if 145-150 CBHP is what you're after, you'll have to mod the cylinders to look like stock Ultras, and be on your own warranty-wise. Sure, the unscrupulous will be able to sneak a deto'd piston or two through on warranty, but a ported cylinder is typically a non-warranty cylinder.

Engine speed may be an area of concern. According to some Yamaha sources, a potentially difficult resonant frequency occurs in the lightweight crankshaft at 8800 to 9000 RPM, so we'll have to pay attention to subscribers' field results when operating the engines in this range.

Last fall, while we were doing dyno testing on a prototype turbocharged 700SX engine, the crank twisted out of phase at only 100 lb/ft of torque the tenth time it was overreved on the dyno (the turbo 700SX power peak was at 8250) to 9000 RPM. While the power output with the turbo was good, the project was shelved temporarily until crankshaft durability is assured. This is not to say that all 700SX cranks need to be welded for safe 9000 RPM operation, especially if they're putting out 80-ish lb/ft of torque, but the existance of this resonant frequency is something to be aware of.

Checking approximate crankshaft phasing on a triple is done easily with a pencil inserted through the spark plug hole to the piston dome...bring the PTO piston to approximate TDC, and the middle and mag pistons should be at the same height...when crankshafts twist out of phase enough to affect power and/or cause detonation from incorrect ignition timing, it's easily discernable with this visual check...out of phase cranks often run smoothly with no change in vibration.

As we can plainly see with the Bender silencer, the additional midrange and top end horsepower increase is the result of MORE airflow. Typically, when backpressure is decreased, power levels drop. Aftermarket silencers sometimes add power by increasing backpressure and lowering airflow, which is good for trail riders and draggers, but not for long run lakeracers and hillclimbers. Not so with the 700SX; the Bender silencer is less restrictive than stock and makes more power by increasing the flow through the meager exhaust ports, especially at low RPM. According to Kevin Cameron, this fact supports the contention that the exhaust port area and timing is ultra-conservative.

The additional airflow is also a positive for those who desire to operate the sled for long periods at WOT, further ensuring the "purging" of residual exhaust gases and deto-promoting active radicals from the cylinders prior to exhaust port closure.

At press time, no production triple pipes or aftermarket reeds/cages had been tested. That will be done shortly.

Note that the stock jetting gave us lean low .60's BSFC at 40 degrees F. Carb float bowls on this model are vented under the hood, while the airbox inlet is behind the windshield. It is likely that the underhood pressure will be slightly higher at high speeds, allowing the engine to be safely rich even at sub-zero temperatures.

It will be interesting to check this with our magnehelic gause like we did with the VMax 4 in Vol 4., no. 3.

1997 STOCK YAMAHA 700SX
145/143/143 MJ

Data for 29.92 Inches Hg. 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .745
Vapor Pressure: .20
Barometer: 30.43

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
6750	66.5	85.5	57.4	152.3	12.2	.65	41
7000	67.0	89.3	59.1	157.1	12.2	.64	40
7250	68.8	95.0	64.4	161.7	11.5	.66	41
7500	71.3	101.8	66.6	167.7	11.6	.63	41
7750	72.4	106.8	69.1	172.4	11.5	.63	42
8000	72.4	110.3	68.6	176.4	11.8	.60	41
8250	71.2	111.8	70.3	176.3	11.5	.61	41
8500	68.7	111.2	71.9	176.4	11.3	.62	40
8750	65.6	109.3	73.1	176.5	11.1	.65	41

1997 STOCK YAMAHA 700SX
145/143/143 MJ--BENDER RACING SILENCER

Data for 29.92 Inches Hg. 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .745
Vapor Pressure: .20
Barometer: 30.43

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
6750	70.5	90.6	63.9	162.0	11.6	.68	40
7000	75.2	100.2	70.3	171.5	11.2	.68	39
7250	75.7	104.5	71.8	176.7	11.3	.66	39
7500	75.4	107.7	72.5	180.8	11.5	.65	39
7750	74.8	110.4	71.7	184.8	11.8	.63	39
8000	74.0	112.7	70.2	186.7	12.2	.60	40
8250	72.9	114.5	73.4	187.8	11.7	.62	40
8500	70.9	114.7	76.7	189.4	11.3	.65	40
8750	68.1	113.5	78.0	190.0	11.2	.66	40

1997 POLARIS 700RMK

Here's the newest Polaris production engine. This is a case reed twin cylinder, single pipe engine that is made by Polaris. The "made in the USA" letters cast in the cylinder head indicate that this is a non-Fuji engine, designed to provide high horsepower in a fashionably light weight package.

Polaris has chosen to use Kehein 38mm flatslide carbs on this engine. While most of us are used to dealing with Mikuni carburetors on high performance snowmobile engines, Kehein carbs provide equal flexibility for tuning and altering the fuel delivery curve for various style engines. It's done a bit differently; all-new jetting components will require us to add another $1000 drawer to our dyno "brass" inventory. We'll have to analyze the fine tuning of these carbs as soon as Joe Dispirito fires up his single cylinder test engine.

On this engine, Polaris decided to inject part of its lubricating oil directly to the outboard main bearings, and the rest of the oil into the fuel pump as Yamaha does, ostensibly to lubricate the carbs' slides and prevent sticking. As is the case with the Yamahas, the variable ratio oil mixture is rendered haphazard by this change, but is no big deal in terms of reliability. If you operate the sled at, say, 1/8th throttle for a mile, the fuel pump, fuel lines and float bowls will be filled with 80-1 "premix". Then, whack the throttle open and the engine screams on the 80-1 mix for a couple of hundred yards while the pump, lines and float bowls finally fill with 20-1 premix, probably as you've backed off to cruise slowly, (and smokily) as the "rich" stuff is gradually consumed before the cycle is repeated. It's a goofy way to lube an engine, but apparently the slides need the lubrication.

The 700RMK came with high altitude jet specs in the carbs, which we didn't realize until we had made several wickedly lean, hot dyno pulls (125-126 CBHP at .52 LB/HPHR!). We had expected typical conservative sea level jetting and quite frankly didn't pay attention to the BSFC numbers as we made out initial tests- instead, we had our eyes glued to the horsepower numbers as the new engine accelerated through its RPM range on the dyno. The fact that the engine did not detonate during the first few inadvertantly lean passes on 93 octane gasoline is a good indication that this engine will be relatively deto-resistant.

Our current lack of tuning components necessitated redrilling our RMK's main jets to what should approximate a 175 size. This resulted in the following dyno data. BSFC is still perhaps a bit low (Polaris engineers typically like to see .65-.70 LB/HPHR), and until we test our first true sea level 700 twin, this is our best estimate of the relative performance the engine will deliver. This data was with the pipe moderately hot, as it might be in typical trail riding conditions. Generally, the power peak occurs at 7750 RPM initially and gradually slides up to 8000 RPM, and possibly even higher on long lake or mountain blasts. This single pipe obviously does not like to be overreved; allowing the clutch to operate even 250 RPM past the power peak can cost 40 HP! It's usually better to underrev than overrev.

In early 1997, we'll have a new 700XP, which is the same engine in the light weight chassis, along with some reeds, aftermarket twin pipes, etc.

1997 STOCK POLARIS 700 RMK #35
175 MJ
Data for 29.92 Inches Hg. 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .744
Vapor Pressure: .18
Barometer: 30.56

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
6500	67.8	83.9	62.1	140.2	10.4	.72	50
6750	74.0	95.1	66.1	145.7	10.1	.68	52
7000	77.2	102.9	69.8	153.0	10.1	.66	52
7250	79.0	109.1	72.8	160.5	10.1	.65	50
7500	80.3	114.7	73.3	167.2	10.5	.62	49
7750	82.7	122.0	75.8	172.6	10.5	.60	50
8000	80.2	122.2	78.5	175.1	10.2	.62	50
8250	50.8	79.8	75.4	169.1	10.3	.92	51
8500	40.2	65.1	71.9	161.0	10.3	1.07	50

1996 ski doo MXZ 670

Performance Improvements

Billy Howard, of Howard's Motorsports in Coudersport, PA (814-274-9800) brought this 670 Rotax to the dyno for evaluation. We wanted to compare the new-style side outlet pipe with the early rear outlet pipe, as well as optimize ignition and rotary valve timing.

For our testing, the stock airbox was retained, and 300-270 main jets were installed to compensate for the 40 degree CAT. As we can see from the .60 BSFC (SkiDoo typically likes .65 to .70 to remain safe with pump gas on long, long runs at WOT) it is likely that this chassis with underhood carb float bowl venting and cowl air intake results in high speed enrichening of the A/F mixture. This is another machine that warrants high speed documentation with our magnahelic gauge.

1996 MXZ 670 1996 STOCK PIPE
300-270 MJ

Data for 29.92 Inches Hg. 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .748
Vapor Pressure: .13
Barometer: 29.98

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
5000	54.8	52.2	36.3	96.5	12.2	.68	41
5250	58.8	58.6	44.3	105.5	10.9	.74	41
5500	62.0	64.9	51.7	112.2	10.0	.78	41
5750	63.3	69.3	54.9	118.9	9.9	.78	41
6000	66.0	75.4	57.5	125.8	10.0	.75	41
6250	68.2	81.2	57.5	130.1	10.4	.70	41
6500	69.5	86.0	55.7	133.4	11.0	.64	41
6750	75.8	97.4	59.0	140.0	10.9	.59	41
7000	78.1	104.1	63.8	144.8	10.4	.60	40
7250	79.2	109.3	67.8	147.7	10.0	.61	40
7500	81.3	116.1	70.6	154.0	10.0	.60	40
7750	79.3	117.0	73.4	158.0	9.9	.61	40
8000	76.4	116.4	75.9	160.7	9.7	.64	40

Next, we installed a 1995 stock pipe and cannister, which uses a conventional rear outlet. This gave us reduced horsepower output throughout the RPM range. The early rear outlet pipe is reportedly the same dimensions as the new side outlet pipe, with only the placement of the exhaust exit being different.

1996 MXZ 670
300-270 MJ--1995 STOCK PIPE

Data for 29.92 Inches Hg. 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .748
Vapor Pressure: .13 Barometer: 29.98

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
5250	59.0	59.0	50.3	110.8	10.1	.84	43
5500	61.5	64.4	54.3	115.7	9.8	.83	42
5750	60.7	66.5	54.8	120.5	10.1	.81	43
6000	62.5	71.4	56.4	124.6	10.1	.78	43
6250	64.6	76.9	56.7	129.3	10.5	.73	43
6500	71.5	88.5	57.3	137.0	11.0	.64	43
6750	73.7	94.7	63.9	141.5	10.2	.66	42
7000	77.0	102.6	64.4	147.0	10.5	.62	43
7250	78.8	108.8	67.5	151.2	10.3	.61	42
7500	79.2	113.1	71.3	154.6	10.0	.62	41
7750	78.1	115.2	73.0	157.5	9.9	.62	42
8000	75.2	114.5	73.7	159.6	9.9	.63	42
8250	61.7	96.9	73.8	158.0	9.8	.75	43
8500	38.6	62.5	72.1	149.5	9.5	1.13	43

The 1996-1997 pipe and cannister were reinstalled, and the conveniently accessable ignition timing was advanced from the stock .078" BTC to .088" BTC. This resulted in a less forgiving for low octane gasoline spec, and a one HP gain throughout the powerband.

1996 MXZ 670 1996 STOCK PIPE
300-270 MJ
ADVANCE TIMING .010"

Data for 29.92 Inches Hg. 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .748
Vapor Pressure: .13 Barometer: 29.98

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
5250	58.6	58.6	47.8	106.8	10.3	.80	41
5500	62.1	65.8	53.1	112.3	9.7	.80	41
5750	64.6	70.7	55.6	119.9	9.9	.77	41
6000	66.2	75.6	58.0	126.0	10.0	.75	40
6250	68.1	81.0	58.4	130.0	10.2	.71	40
6500	69.2	85.6	57.8	132.5	10.5	.66	41
6750	73.0	93.8	61.1	138.0	10.4	.64	41
7000	78.2	104.2	65.2	144.5	10.2	.61	41
7250	79.8	110.2	67.2	148.0	10.1	.60	41
7500	81.4	116.2	70.4	151.7	9.9	.59	41
7750	80.2	118.3	74.6	157.4	9.7	.62	41
8000	77.0	117.3	76.3	161.3	9.7	.64	40

The stock 501 rotary valve was replaced methodically by several different rotary valves. The best combination we found was a fiber 500 rotary valve. This new valve had a 70-143 timing, compared to 78-135 stock. We received power improvement throughout the RPM range.

1996 MXZ 670--1996 STOCK PIPE--500 RV
300-270 MJ
ADVANCE TIMING .010"

Data for 29.92 Inches Hg. 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .748
Vapor Pressure: .13 Barometer: 29.98

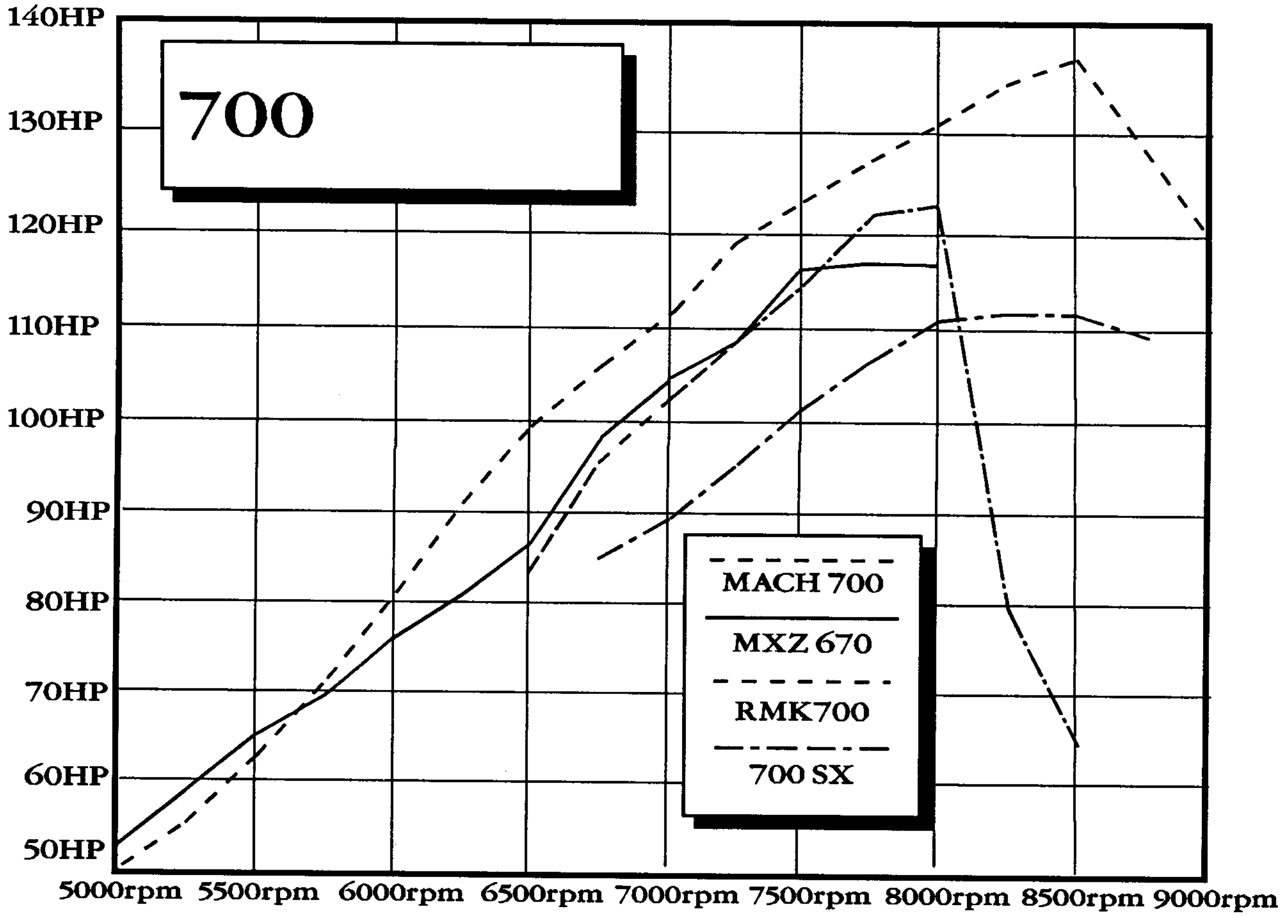
RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
5000	54.6	52.0	39.2	93.5	11.0	.74	42
5250	58.6	58.6	44.2	104.7	10.9	.74	42
5500	62.8	65.8	51.7	113.1	10.0	.77	42
5750	64.9	71.1	56.7	121.1	9.8	.79	43
6000	66.6	76.1	59.0	126.8	9.9	.76	44
6250	67.2	80.0	61.1	129.8	9.8	.75	44
6500	71.3	88.2	62.8	135.7	9.9	.70	43
6750	75.9	97.5	64.2	140.5	10.1	.65	43
7000	77.2	102.9	67.6	144.1	9.8	.65	43
7250	80.1	110.6	69.3	148.6	9.8	.62	43
7500	81.9	117.0	74.9	154.9	9.5	.63	43
7750	80.8	119.2	76.2	158.2	9.5	.63	43
8000	77.4	117.9	76.2	161.1	9.7	.64	42

We did several other tests involving moving the stock rotary valve disc around. The optimum rotary valve timing was with the stock valve retarded 4 degrees, for a timing of 82-137. This gave us just a bit less midrange, and slightly better overrev power than the 500 valve tested earlier.

1996 MXZ 670 STOCK PIPE--RETARD RV 4 DEG.
300-270 MJ --ADVANCE TIMING .010"

Data for 29.92 Inches Hg. 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .748
Vapor Pressure: .13 Barometer: 29.97

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
5000	54.6	52.0	41.3	96.2	10.7	.78	42
5250	58.0	58.0	48.2	104.5	10.0	.82	41
5500	61.5	64.4	53.4	110.6	9.5	.81	39
5750	63.3	69.3	55.1	116.9	9.7	.78	39
6000	66.6	76.1	57.3	123.1	9.9	.74	39
6250	67.2	80.0	58.1	126.6	10.0	.71	39
6500	70.7	87.5	58.8	130.3	10.2	.66	41
6750	75.7	97.3	60.7	135.6	10.3	.61	41
7000	78.5	104.6	66.4	140.6	9.7	.62	40
7250	81.4	112.4	67.2	144.5	9.9	.59	41
7500	82.3	117.5	70.6	149.8	9.7	.59	40
7750	80.8	119.2	73.8	153.9	9.6	.61	38
8000	77.4	117.9	75.2	158.2	9.7	.63	39



Dear subscribers:

WELCOME, AT LONG LAST ... to the seventh volume of DynoTech. We're close to being back on track now. Thanks for your patience.

Many old time subscribers have followed the continuing saga of C&H Welding Supply, C&H Dyno Service, DynoTech, and most recently our involvement with First Choice Turbo Center/Aerocharger Turbo Systems.

Two years ago, I sold my welding supply and compressed gas business to help capitalize the long term acquisition of AeroDyne Dallas, the designer and manufacturer of the Aerocharger (the Aerocharger is a patented self-lubricating turbocharger with variable pitch exhaust vanes surrounding the exhaust turbine, which virtually eliminate turbo lag).

Besides my personal equity cash infusion into Aerodyne Corp., we are still trying to raise the additional capital required to complete the acquisition of the Aerocharger and to develop and market new applications (industrial, Harley-Davidson, automotive, etc.). Working on raising this additional capital has been rewarding but extremely time consuming, dealing with accountants, attorneys and investors. It's been great fun, though it's been at the expense of our DynoTech subscribers. The final phase of the capitalization is expected to be completed this calendar year. That, coupled with rapid growth of the sales of Harley turbo systems (stock 1340 Harleys have 50 HP and 60LB/FT, Aerocharged they are reliable with 100 HP and 110 LB/FT on pump gas!) has temporarily reduced the time available for dyno testing and technical journalism.

I expect to complete the final phase of our capitalization early 1997, and I can then devote more time to placing the information on paper. I believe that we can be back on track soon.

Yours truly,

Jim Czekala

Dyno-nics--Language of the Dyno

Understanding the information we receive from the dyno is necessary to get the full benefit from this technical journal. Most importantly are horsepower and where it occurs, but the other data provides equally valuable insight into the performance of an engine.

All of our data is listed as "Standard Corrected". This is the expected performance the engine would produce when tested at sea level (29.92 inches of mercury), 60 degree dry air. High humidity, low barometric pressure, and high air temperature reduce observed (uncorrected) horsepower. Conversely, high barometric pressure and low air temperature increase an engine's power output.
The "Standard Correction" factor considers the operating conditions and adjusts, or corrects, the data accordingly.

RPM Engine speed, Revolutions Per Minute.

CORRECTED BRAKE TORQUE Twisting force exerted by the crankshaft, in units called "pound-feet". Torque measurement does not take into consideration any movement of the shaft.

CORRECTED BRAKE HORSEPOWER The torque producing, spinning crankshaft's ability to do work, derived from the mathematical formula Torque x RPM/ 5252. A high speed, low torque, spinning shaft can do the same amount of "work", and achieve the same

→

horsepower output as a low speed, high torque, spinning shaft.

FUEL FLOW *Amount of fuel, measured as pounds per hour, entering the engine's carburetor(s) during operation. Depending upon the amount of an engine's carb vibration, this measurement can sometimes be difficult to interpolate. Usually, this is accurate enough to jet by; Mikuni hex jet sizes are directly proportional to their fuel flow.*

AIR FLOW-SCFM *or Standard Cubic Feet per Minute of air flowing through the engine. This can be confusing at times, as an identical engine will flow more SCFM in the winter than it will in less dense summer air. This is perhaps our crudest measurement, due to airbox air leaks in drain holes, ill-fitting carb flanges, etc.*

A/F RATIO *Pounds of air consumed per pound of fuel. 10-1 is rich, bordering on misfire. 12-1 is around maximum power production. 17-1 is bordering on lean misfire. Like the AIR FLOW reading, this is only as accurate as the fit and sealing of the airbox feeding the carbs.*

BSFC *Pounds of fuel consumed per OBSERVED ("uncorrected") horsepower per hour. Our own very general assessment is that .50 to .59 is lean, maximum power, on the edge for short runs. .60 to .69 is safe jetting, decent power output, 92 octane safe on conservative compression engines. .70 to .79 is ultra-safe, good for long periods of time at full throttle, even on sub-92 octane or oxygenated gas.*

CAT *Carburetor Air Temperature as it enters the airbox while the engine is tested on the dyno. This is the temperature that is used by the computer to determine the "corrected" torque and power, and the temperature you should use as a baseline for jetting using our specs.*

ON KEVIN CAMERON

I owe much of the success here to our technical editor Kevin Cameron. I've bugged him many, many times when something new to us would occur on the dyno, and he's always been able to explain why in terms that we all can understand. Kevin's comparing the detonating, high-powered aftermarket piped Ultra's combustion chambers to a crowded bar room is typical of his descriptions of seemingly unexplainable phenomena.

The greatest single thing our dyno did for the average performance snowmobiler was to show us where the engines' true horsepower peaks were. At the time, I couldn't understand why the factories missed their sleds' power peaks, but Kevin cleared up that mystery (see Vol 5, no. 6 on pipe temperature).

By the time we (I) had detonated, seized, or "gripped" a hundred or so pistons on the dyno, it became obvious that a fairly constant, universal pattern had developed for what would be safe maximum power jetting on gasolines of varying octane. This would prove to be another great tuning tool; the Brake Specific Fuel Consumption (pound of fuel per hour per horsepower) that was so foreign to us at first became the prominent display on our digital readout.

Fuel freshness, long neglected by everyone, became another area of intense interest. Kevin Cameron helped us on that one after we seized piston after piston with cool EGT's, high fuel flow numbers, safe A/F ratios on incredibly high octane race gas. Kevin explained the importance of the gradually diminishing "whoosh" of pressure escaping from our fuel drum each time we opened it. Once the whoosh is gone, so are the "light ends" of the gasoline. Half-full liters of Pepsi stored in the refrigerator lose their carbonation the same way. Now, we keep the important "light ends", so necessary to help begin the vaporization process, safely dissolved in our stored race gas with low pressure nitrogen gas. The popular "Fuel Safe" fuel dispensing and blanketing nitrogen kits were developed after this phenomenon was understood. Carl McQuillen Racing in LeRoy, NY (716-768-2322) sells these systems to users of drummed gasoline all over the world.

Our understanding of the importance of fuel freshness was useful recently when the Canadian turbo owner's 600SX tested in this issue was unable to exceed 160 CBHP on the dyno, regardless of boost level or jetting. After we discovered that the C14 gas in the sled was eight months old, we replaced it with our own fresh race gas, and another 45 horsepower was realized, to everyone's delight.

Detonation, which is the bane of all performance snowmobilers, is now an understandable, even sometimes predictable, phenomenon thanks to Kevin's input in the many articles he's done for us on this subject.

GROSS GENERALIZATIONS ABOUT BIG ENGINES

For many years, "big bore" snowmobile engines used to amaze us with their inability to produce more airflow and power than stock bore engines. Limited crankcase volume and transfer port area very likely had to be the key. Big Bore Phazers, 440 SRX Yamahas poked out to 533, SkiDoo 521's opened up to 580 (Formula +++ in V1#1), Arctic Cat 800 Wildcats, larger than 650cc Polaris triples, Yamaha Vmax 540 and 600 engines bored to 650 or whatever, and countless others usually failed to produce more peak power than did similarly ported stock bore engines.

Larry Audette used to complain about having to spend hours tediously grinding material out of the inside of the *crankcases to enable his Crankshop big bore triples to make more power than stock bore triples. What ever happened to "stuffing" crankshafts and crankcases? Several years ago, Tim Bender was desperately searching for more power in the FIII Exciter race (?) engine. Kevin Cameron suggested that he enlarge the crankcase volume to see if that would help. For an easier to accomplish experiment, Tim instead stuffed the crankcase and crankshaft with some epoxy bondo stuff that lasted about three minutes as the "stuffed" engine ran on the dyno, making less horsepower than before. The power output further diminished when the bondo began crumbling loose, covering the dyno walls with a gray plume of difficult to clean up oil/powder residue that billowed intermittantly first from the mag stinger, then from both. That night, Tim disassembled the engine, chipped out the remaining filler from the crankpins and crankcase, and laboriously ground out some additional material to enlarge the crankcase volume. The enlarged crankcase resulted in a measurable power gain.*

Today, however, things have changed (see the big-bore articles in this issue). Now, many new large-crankcase engines, such as the case reed SkiDoo, Cat and Polaris triples, seemed to be made to bore. The XCR 600SP, for example, is very average as a 600, is better as a 680, and really begins to come into its own as a 750 or 800. The huge crankcase likes bigger cylinders--even 1000cc cast cylinders work wonders on the 600 bottom end. The 800 Storm seems happier as a 900 or 1000. 900 Cats make great power at 1000+ cc's. 800 Cats don't seem to respond as well to overbore--engine builders blame that phenomenon on the rear booster ports, cast differently on the 800 cylinders, that become ineffective when overbored.

Even the smallish crankcase on the ZRT 600 handles 700 size cylinders nicely.

The most powerful Yamaha 4 cylinder dragrace engines we've dyno tested have been the 800-860cc. Larger bore and even long-stroked versions of the V-Max up to 1000cc have been tried here, with results at best equal to the smaller versions. Does the Yamaha's limitation result from minimal case volume or transfer ports?

To GENERALIZE again, even though the V-Max 4 engine seems to be the worst candidate for boring, it has shown us that it is capable of making the highest output as an 800cc "prostock" engine, compared with 800cc full mod Storms and Cats we've seen on our dyno. Recently, though, 800cc factory-built, improved stock SkiDoos have shown power output comparable to the best 800cc pro stock Yamahas.

The most powerful 1000cc open improved and prostock SkiDoos, Cats, and Storms we've tested all are capable of producing 225-240+ CBHP on cold drag runs.

But let's not brag about 220 CBHP 800cc snowmobile race engines.

Recently, two DynoTech subscribers from New Zealand stopped to see our dyno facility. These fellows are involved in building, tuning, and racing two-stroke roadracing motorcycles, and were in the U.S. purchasing dynamometer equipment. They had never seen a snowmobile up close, and when I showed them a V-Max 4 in the back shop, they looked at each other in amazement, and laughed at the "antique" engine. They didn't mean to make fun of us snowmobilers--they were just surprised at the 1960's motorcycle technology being foisted upon us by the manufacturers. The New Zealanders' tiny 500cc two-stroke race engines make 200 CBHP, with a BMEP of 200 PSI, broad powerbands and plenty of overrev power. The back straights of some tracks are miles long, not 500 feet. Why don't snowmobile engines use this modern two-stroke technology? I couldn't answer that. Perhaps Kevin Cameron can elaborate on that issue.

Besides his jounalistic endeavors, KEVIN CAMERON does consulting work, at reasonable rates, for individuals and businesses. For example, Ross Liberty of Factory Pipes (a California based pipe stamping and Personal WaterCraft high performance company), uses Kevin Cameron periodically for telphone consultation. Ross has told me that Kevin has been helpful on many projects he's been involved in.

Anyone interested in tapping this great resource should contact me.

NOT TOO INTERESTING HISTORICAL DRIVEL FOR NEW SUBSCRIBERS...

DynoTech began in the mid-eighties, stock snowmobile horsepower levels were an unpublished, dark secret. Snowmobile performance enthusiasts who desired additional performance depended on engine modifiers and parts vendors who advertised sometimes incredible gains from cut ports, big carbs and replacement exhaust pipes.

Like a lot of you, I had spent way too much money on stock sleds that didn't deliver, and too much more money on modifications and parts that provided unsatisfactory, even less than stock performance. I really needed the use of a dyno to see what was going on. Since there was no place to go to test my snowmobiles, I decided to build my own dyno facility.

In 1986, I purchased an awfully expensive SuperFlow car engine dynamometer and hacked it up to something that would allow us to test our snowmobile engines without having to remove the engines from the chassis. I had been attracted to the SuperFlow dyno because it did all of the engine testing by computer control and recording of the data. Conventional dynos require skill *and dexterity to control engine speed with a torque measuring brake so that data can be measured at various speeds. Since I possess limited levels of skill and dexterity, I thought that it would be wise to let a computer do the work. Plus, the SuperFlow dyno had the unique ability to record the data as the engine was accelerating from low to high RPM at predetermined rates.*

We would discover later that this more closely simulated real-world conditions compared with tortuous step-and-hold testing which everyone else did back then. Most importantly, the SuperFlow dyno came with a cool-looking blue control console that would surely make me look like Smokey Yunick when I sat in front of all those swinging needles and flashing red digital readouts. I knew that horsepower was what we were interested in, but I had no idea then what all of this other data meant--torque, fuel flow, air flow, BSFC, etc., but I knew it had to be recorded and somehow figured out. It was obvious that a computer data acquisition system would be best for this.

After the dyno was purchased, a 6,000 lb. capacity hydraulic lift was commandeered from a closed Westinghouse foundry to safely and securely lift our machines high enough so that a slender, torsionally dampened drive shaft could be slipped through a 2" hole in the bellypan to attach the crank taper to the computerized dyno's power absorption unit. A huge squirrel cage blower was set on the roof to duct outside air down and across the sleds.

No one could have forseen the impact that what many said was a goofy idea would eventually have on high performance snowmobiling.

Back then, 90-100 HP was the maximum stock power available from top-of-the-line performance sleds. 650 Cats and Indys provided what was then an incredible 100+ HP. Smaller Formula Plus and Exciter twins had a bit less, but the SkiDoo and Yamaha loyalists were happy just the same, especially when they used the dyno to fine-tune their underdog machines which could easily out-accelerate untuned bigger sleds.

The learning curve from the dyno testing done here has been accelerated greatly because of the fact that lots of smart, industrious people made use of my dyno while I pushed the buttons. Tim Bender, Larry Audette, Brec Norton, Dale and Dan Roes, Rob Schooping, Greg Balchin, Paul Gast and Joe DiSpirito were among the first savvy engine tuners to turn our dyno data into competitive engines, parts and dollars. Today, most of those guys have their own computerized dyno facilities. I like to think that the Big East performance was born here.

Now you don't have to spend $100 G's on a dyno; $4000 DynoMites provide just enough info for most moderate horsepower applications, especially those fitted with fuel flow readouts. Relatively inexpensive DePac computerized instrumentation systems can be fitted to any basic absorption unit, and give users all the info we have here for a reasonable price! New Huff Technology hydraulic brakes and computers are gaining popularity, with great controllability and low initial expense. DynoPort and D&D Cycles had great success with their Huff units, and HTG Racing recently acquired one.

All dyno tesing is as good as the repeatability of the engines. The key is having a constant environment in the testing area. Having 10,000 CFM of fresh outside air to feed a 200 CFM engine is not excessive. Constant air temperature and constant coolant temperature are vital to keep an engine doing the same thing time after time. We use whatever outside air is available, and have our water tank thermostat set to maintain engine coolant temperature at 80-85 degrees F. Constant pipe temperature is another variable that is necessary to understand and control to have a 150 CBHP two-stroke engine repeat within a few tenths of a horsepower on successive test runs.

Torsional vibrations emitted from crankshafts must be dampened to prevent the engines from self-destructing against the ungiving, granite-like load of a heavy dyno absorption unit. Rubber couplers are an excellent means to achieve this. Dyno horror stories of snapped grade eight engine mounting bolts, broken engine cases and twisted crankshafts are common, but all of these are preventable if steps are taken to control impact-wrench-like torsional vibrations.

Understanding the information we receive from the dyno is necessary to get the full benefit from DynoTech. Most importantly are horsepower and where it occurs, but the other data provides equally valuable insight into the performance of an engine.

POLARIS 680 SPX comparison BIG BORE 600 SPs

Cooper Sales and Service of Waterport, NY brought this new Ultra 680 SPX for dyno evaluation.

Basically, this sled/engine combo is an XCR 600SP with larger bore to 680cc, identical engine, colliding stream cylinders, high flow airbox, same pipe set part number, etc. This is the next logical step for the 600SP; the larger engine displacement lets the pipe/cannister combination work well even when cool. This early production model had .060" squish clearance. Later versions have even tighter, .050" squish clearance.

The power peak on this engine varies from 8250 to 8500 depending upon pipe temperature. On this test, we can interpolate the data to assume an 8350 RPM power peak.

330 main jets were installed in place of the stock 380 mains to compensate for our 65 degree F CAT on the day of the test.

1997 680 ULTRA SPX 330 MJ
Data for 29.92 Inches Hg. 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .745
Vapor Pressure: .40 Barometer: 30.09

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
6500	67.1	83.0	66.3	155.5	10.8	.81	63
6750	68.6	88.2	69.0	156.6	10.4	.79	64
7000	73.9	98.5	75.8	167.4	10.1	.78	64
7250	76.8	106.0	88.3	176.2	9.2	.84	64
7500	79.9	114.1	86.8	180.8	9.6	.77	64
7750	81.5	120.3	91.5	185.4	9.3	.77	65
8000	83.9	127.8	86.9	193.0	10.2	.69	65
8250	84.7	133.0	92.4	202.5	10.1	.70	63
8500	81.9	132.5	99.6	210.6	9.7	.70	63
8750	74.8	124.6	95.9	209.7	10.0	.79	63

750 Nickasil Big Bore XCR600

...the way it should have been PART I

Mike Murray of Sport Vehicle Village in Stafford, NY bored and renickasiled this XCR600SP engine to accept stock 750 Storm pistons and rings. He left the port timing identical to the stock XCR600SP, and machined the heads with a very generous (safe) .080" squish clearance and 130 psi cranking compression. Stock pipes, cannister, and stock reeds are used here. While we had taped our airflow meter to the airbox top, excessive leakage between the airbox halves and leaks at the rubber carb flanges prevented us from obtaining meaningful airflow data which would have been interesting. This engine, tested in the chassis, also exibited fluctuating fuel flow that probably does not affect the operation of the engine. It would be interesting to see if this engine would have more constant fuel flow, like our 680 Ultra did last year, with the addition of 1.8mm needle and seats. Interpolating the fuel flow data, we can see that 360 main jets gave this engine an extremely safe .70 lb/hphr BSFC at 50 degrees F. Tighter squish, leaner jetting, VForce reeds, and DynoPort Storm silencers could easily put this combination into the 150 CBHP range for another $500.

Note that the stock port timing gives this engine excellent low and midrange torque and horsepower compared to the stock 600 and 680, and even compared to the more radically ported but larger displacement 800cc big bore tested in this issue.

Mike has made the offer to duplicate these cylinders and heads for DynoTech subscribers. This modification includes new pistons and rings.

1996 POLARIS XCR 750 BIG BORE--360 MJ/P4 NJ
Data for 29.92 Inches Hg. 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .743
Vapor Pressure: .33 Barometer: 30.23

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
6500	81.9	101.4	63.6	137.9	10.0	.62	54
6750	83.7	107.6	75.0	142.7	8.7	.69	53
7000	86.0	114.6	86.9	146.8	7.8	.75	54
7250	86.4	119.3	92.1	149.7	7.5	.77	55
7500	87.8	125.4	106.7	153.1	6.6	.85	54
7750	90.8	134.0	98.8	157.4	7.3	.73	54
8000	91.4	139.2	101.7	162.4	7.3	.73	53
8250	89.3	140.3	93.9	166.2	8.1	.67	54
8500	82.9	134.2	91.7	166.1	8.3	.68	53
8750	73.6	122.6	96.4	164.4	7.8	.78	53

800 Iron Sleeve Big Bore XCR600

...the way it should have been PART II

Jim and Lynn Cooper of Cooper Sales and Service had HTG Racing in Grand Island, NY build them this correctly bored XCR600SP. HTG used 800 Storm pistons and rings along with new style V-Force reeds to achieve better-than-Storm torque and horsepower out of this engine/pipe combination. The boring, sleeving and re-porting, with combustion chamber modifications are available from HTG.

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The XCR 600SP castings are not conducive to boring and re-nickasil coating to the 800 bore size; sleeves are necessary if one desires to have this displacement engine. While cast iron sleeves can't match the nickasil bore's desirable heat transfer capabilities, they do provide lower maintenance cost for those occasions when detonation might occur.

Comparing this combination to the other XCR 600SP based engines, we can see that the whole package just works correctly. The stock 600 pipes and cannister have more than ample airflow for the 800 bore engine, as evidenced by the power we picked up by adding tighter DynoPort 800 Storm glasspack silencers. We're not really sure about the DynoPort silencers' effect upon reliability; this is a new, untested package that will be run locally on pump gas. Do the silencers cause more packing of active radicals into the cylinders upon exhaust port closing? A follow-up report will be forthcoming on all of these big-bore engines.

1996 POLARIS XCR HTG SLEEVED BIG BORE 800
360 MJ V-FORCE REEDS
STOCK PIPES/STOCK SILENCER
Data for 29.92 Inches Hg. 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .743
Vapor Pressure: .33 Barometer: 30.21

RPM	CBT	CBHP	FUEL	BSFC	CAT
6500	76.7	94.9	88.5	.92	47
6750	83.0	106.7	92.8	.86	47
7000	86.0	114.6	102.4	.88	48
7250	89.0	122.9	106.2	.86	49
7500	91.8	131.1	111.4	.84	49
7750	95.3	140.6	103.6	.73	49
8000	97.0	147.0	115.7	.77	49
8250	95.8	150.5	107.6	.71	49
8500	91.9	148.7	110.4	.73	49

1996 POLARIS XCR HTG SLEEVED BIG BORE 800
360 MJ V-FORCE REEDS
STOCK PIPES/DYNOPORT SILENCERS
Data for 29.92 Inches Hg. 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .743
Vapor Pressure: .33
Barometer: 30.20

RPM	CBT	CBHP	FUEL	BSFC	CAT
6500	78.7	97.4	84.1	.62	54
6750	82.8	106.4	88.6	.69	53
7000	87.9	117.2	102.8	.75	54
7250	89.9	124.1	101.9	.77	55
7500	92.5	132.1	109.3	.85	54
7750	96.9	143.0	108.3	.73	54
8000	100.5	153.1	104.6	.73	53
8250	98.6	154.9	119.3	.67	54
8500	93.9	152.0	102.4	.68	53

PSI BIG BORE 680 ULTRA

more cc's & deto free

John T. Cowie's Ultra 680 was our test mule for our Ultra 680 pipe shootout last season. Because of the repeated detonation we experienced during that particular dyno test session, John T. was understandably cautious last season operating his stock Ultra, switching back and forth from SLP to DynoPort pipes with big mains and retarded timing to keep the engine on or about the 140-145 HP level. John T. never experienced deto last winter, but his sparkplug hole threads were well worn from repeated plug and piston checks.

Bruce Kahlhammer of PSI Performance offered to upgrade John T's time-bomb Ultra to what Bruce predicted would be a deto-free high power pump gas engine that would compliment the lightweight old style Polaris chassis. John shipped his cylinders to PSI, where they were bored to accept stock 750 Storm pistons, ported to a "lake race" spec and re-nicasiled. PSI provided billet replacement heads that had narrow, Rotax-like squish band and a top-hat style combustion chamber. To compliment the heads and improve heat transfer from the domes to the coolant, complex looking swirl-shaped cooling fins were machined into the topsides of the domes.

At Bruce's suggestion, John T's timing was cranked back up to 14 degrees.

PSI modified a set of their Ultra 680 pipes to improve airflow, which would further help eliminate detonation by preventing the re-entry of the active radicals through the exhaust ports. More power can be gained from this combination by reducing airflow, but our quest is to achieve reliability and high power on pump gas. The combination of high flowing pipes, plus a "larger bar room" as Kevin Cameron would describe it, would add up to a reliable race sled on pump gas. Last year, we couldn't get this engine to be reliable as it approached 100 lb/ft of torque. Now, this same engine with 10% additional displacement hums happily on the dyno for 15 seconds at a time on pure (posted) 93 octane gas.

The stock Ultra 680 airbox was retained, as were the stock 38mm carbs. Note the 4% airflow increase resulting from the installation of the old-style V-Force reeds, and also note the corresponding 10% (after interpolating the fuel flow numbers) fuel flow increase. The horsepower increase from the addition of the old-style V-Force reeds might even be greater had we not been afraid to jet down

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PSI BIG BORE
680 ULTRA

more cc's & deto free

a bit. As it is, 163 CBHP at .68 lb/hphr should provide John T with trouble-free fun.

680 ULTRA/750 BIG BORE
PSI PERFORMANCE
PSI BIG BORE PIPES/STOCK REEDS

Data for 29.92 Inches Hg. 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .746
Vapor Pressure: .40
Barometer: 29.97

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
6750	65.9	84.7	81.5	184.8	10.4	.98	69
7000	70.7	94.2	84.2	194.2	10.6	.91	69
7250	76.8	106.0	84.7	205.4	11.1	.82	70
7500	84.0	120.0	87.3	219.0	11.5	.75	70
7750	88.4	130.4	89.3	231.9	11.9	.70	68
8000	91.2	139.9	90.9	237.8	12.0	.67	69
8250	95.5	150.0	94.7	248.1	12.0	.65	69
8500	97.4	157.6	95.7	256.4	12.3	.62	69
8750	95.1	158.4	95.6	258.9	12.4	.62	70
9000	87.3	149.6	95.2	257.6	12.4	.65	68

680 ULTRA/750 BIG BORE
PSI PERFORMANCE
PSI BIG BORE PIPES/V-FORCE REED CAGES

Data for 29.92 Inches Hg. 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .746
Vapor Pressure: .40
Barometer: 29.99

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
6750	68.2	87.7	77.4	197.9	11.7	.90	67
7000	73.0	97.3	82.4	203.6	11.3	.86	67
7250	79.6	109.9	87.3	215.7	11.3	.81	67
7500	86.2	123.1	91.7	225.8	11.3	.76	67
7750	87.3	128.8	100.0	232.4	10.7	.79	67
8000	92.6	141.1	94.0	244.7	12.0	.68	67
8250	98.7	155.0	106.0	258.4	11.2	.70	65
8500	99.3	160.7	110.6	265.8	11.0	.70	65
8750	97.6	162.6	110.1	268.8	11.2	.69	65
9000	73.6	126.1	108.8	263.8	11.1	.88	65

PSI BIG BORE
600 ZRT

the way the 600 Cat could have been

Here's another big bore that works. My new big-bore favorite is this new Cat 600 triple, because it's so small, light, smooth, and seemingly designed for the 440ZR chassis that this particular engine is destined to power for a trail rider in Wisconsin.

We started out testing the big-bore ZRT700 with stock reeds, Larry Bartlett's stock 1996 correctly fit pipes and stock can. Stock 36mm carbs were used. Note the airflow increase compared to stock that can be directly attributable to the increased displacement and porting. Every ZRT600 should have been born a ZRT700.

1996 600 ZRT/700 PSI ENGINE
320 MJ STOCK PIPES/REEDS/AIRBOX

Data for 29.92 Inches Hg. 60 F dry air
Test: 200 RPM/Sec Acceleration
Fuel Specific Gravity: .745
Vapor Pressure: .21 Barometer: 30.22

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
6750	77.0	99.0	81.2	187.3	10.6	.81	46
7000	80.6	107.4	83.4	194.1	10.7	.76	46
7250	84.8	117.1	79.9	199.9	11.5	.67	47
7500	87.5	125.0	80.9	204.7	11.6	.64	46
7750	89.7	132.4	88.9	211.3	10.9	.66	46
8000	91.2	138.9	82.9	214.5	11.9	.59	47
8250	90.5	142.2	87.3	218.2	11.5	.60	47
8500	95.4	138.2	89.7	219.6	11.2	.64	46

Next, we installed early style V-Force reed cages and picked up some more airflow and horsepower. On this test, the stock pipe temperature was a bit higher than the previous test with stock reeds, which would account for the reduced bottom end and midrange power.

1996 600 ZRT/700 PSI PERFORMANCE
320 MJ STOCK PIPES/1996 V-FORCE REEDS

Data for 29.92 Inches Hg. 60 F dry air
Test: 200 RPM/Sec Acceleration
Fuel Specific Gravity: .745
Vapor Pressure: .21Barometer: 30.22

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
7000	78.2	104.2	84.2	190.1	10.4	.79	48
7250	82.9	114.4	84.6	197.6	10.7	.73	48
7500	87.1	124.4	85.4	203.8	11.0	.68	50
7750	90.3	133.2	83.3	212.0	11.7	.62	49
8000	92.2	140.4	82.9	218.8	12.1	.58	49
8250	92.5	145.3	85.0	220.6	11.9	.58	49
8500	88.3	142.9	89.4	220.8	11.3	.62	49
8750	71.3	118.8	89.8	218.7	11.2	.74	49
9000	54.3	93.1	89.7	211.8	10.8	.95	49

PSI BIG BORE 600 ZRT the way the 600 Cat could have been

The stock reeds were reinstalled, and PSI's ZRT600 pipes, which they modify to flow more air for the big bore, replaced the stock pipes. More power would very likely be available with tighter pipes, but that's OK. This is a low octane trail engine, and it needs all the exhaust airflow it can get.

1996 600 ZRT/700 PSI ENGINE
320 MJ--PSI BIG BORE PIPES--STOCK REEDS

Data for 29.92 Inches Hg. 60 F dry air
Test: 200 RPM/Sec Acceleration
Fuel Specific Gravity: .745
Vapor Pressure: .21 Barometer: 30.22

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
7000	73.3	97.7	86.6	198.7	10.5	.87	45
7250	75.1	103.7	83.4	203.6	11.2	.79	44
7500	77.2	110.2	83.8	206.0	11.3	.74	44
7750	78.6	116.0	87.4	207.9	10.9	.74	45
8000	79.2	120.6	84.1	209.9	11.5	.68	45
8250	80.2	126.0	81.9	212.4	11.9	.64	45
8500	81.6	132.1	87.7	215.3	11.3	.65	45
8750	84.8	141.3	88.2	224.4	11.7	.61	46
9000	84.7	145.1	94.1	232.1	11.3	.64	45
9250	82.6	145.5	91.4	237.0	11.9	.62	45
9500	74.0	133.9	100.4	238.7	10.9	.73	45

The early style V-Force reeds were put in place of the stock reed cages, and airflow and HP increased as follows. Note that the VForce reeds appeared to reduce the fuel flow when coupled with the PSI pipes.

1996 600 ZRT/700 PSI ENGINE
320 MJ--PSI BIG BORE PIPES
V-FORCE REEDS

Data for 29.92 Inches Hg. 60 F dry air
Test: 200 RPM/Sec Acceleration
Fuel Specific Gravity: .745
Vapor Pressure: .21 Barometer: 30.20

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
7000	70.9	94.5	78.6	200.6	11.7	.82	48
7250	74.8	103.3	79.9	206.4	11.9	.76	47
7500	77.2	110.2	81.2	210.9	11.9	.72	47
7750	80.0	118.1	82.4	214.0	11.9	.69	49
8000	80.3	122.3	77.7	216.4	12.8	.63	48
8250	81.5	128.0	77.0	219.7	13.1	.59	48
8500	82.5	133.5	74.3	223.1	13.8	.55	48
8750	86.7	144.4	82.7	230.0	12.8	.56	48
9000	86.0	147.4	90.9	236.1	11.9	.61	48
9250	84.0	147.9	89.6	239.6	12.3	.60	48
9500	80.0	144.7	88.5	240.5	12.5	.60	48

Finally, the airbox was removed from the engine, as it will be run in the ZR440 chassis that way. In this case, seeing the fuel flow increase along with horsepower, we can assume that airflow has similarly increased. Here we have the makings of what many would consider an ideal trail sled–150 CBHP in a 500 lb chassis.

1996 600 ZRT/700 PSI ENGINE
320 MJ--PSI BIG BORE PIPES--V-FORCE REEDS
NO AIRBOX

Data for 29.92 Inches Hg. 60 F dry air
Test: 200 RPM/Sec Acceleration
Fuel Specific Gravity: .745
Vapor Pressure: .21
Barometer: 30.18

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
7000	73.1	97.4	71.4	200.6	11.7	.82	48
7250	76.7	105.9	72.7	206.4	11.9	.76	47
7500	79.0	112.8	77.2	210.9	11.9	.72	47
7750	79.6	117.5	82.3	214.0	11.9	.69	49
8000	82.1	125.1	88.8	216.4	12.8	.63	48
8250	84.9	133.4	88.5	219.7	13.1	.59	48
8500	86.3	139.7	90.4	223.1	13.8	.55	48
8750	88.1	146.8	90.7	230.0	12.8	.56	48
9000	87.6	150.1	92.9	236.1	11.9	.61	48
9250	85.5	150.6	93.6	239.6	12.3	.60	48
9500	78.0	141.1	95.6	240.5	12.5	.60	48

Following are the phone numbers of the companies whose products were tested for our big bore comparison.

Hot to Go Racing	**716-773-6131**
PSI Performance	**414-622-4555**
Sport Vehicle Village	**716-343-3033**

V-Force Reeds are available from a number of dealers nationwide.

1997 AEROCHARGED

POLARIS RMK 700 & YAMAHA 600 SX

Polaris 700 RMK

We've seen three case reed triple engines (Storm, Ultra, Thundercat) that when turbocharged failed to deliver horsepower levels that would warrant a $2500-3000 investment like a turbo system, even for high altitude mountain riding.

The Polaris 700cc case reed twin has suprised us with great torque and horsepower levels that should please sea level riders as well as those who ride at 10,000+ ft altitude where Storms accelerate like Trail Indys do at sea level.

Besides the excellent power output per pound of boost, the turbo 700RMK delivers dragster-like, lag-free takeoffs with a sub-5000 RPM clutch engagement.

Though extensive tuning and R&D would surely enable the stock Kehein carbs to be used with the turbo, Mikuni 38VMs are used here with predictable results.

AEROCHARGED 1997 POLARIS 700 RMK
380/360 MJ 6.5 PSI BOOST PUMP GAS

Data for 29.92 Inches Hg. 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .735
Vapor Pressure: .19
Barometer: 30.07

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
5500	70.5	73.8	58.2	154.4	12.1	.79	43
5750	72.4	79.3	59.3	161.1	12.5	.75	43
6000	78.2	89.3	61.1	174.3	13.1	.68	41
6250	83.5	99.4	64.7	182.3	12.9	.65	41
6500	85.3	105.6	66.9	190.1	13.0	.63	41
6750	91.0	117.0	67.6	196.0	13.3	.58	43
7000	91.5	122.0	77.4	201.9	12.0	.63	43
7250	91.0	125.6	83.9	207.1	11.3	.67	43
7500	90.4	129.1	90.1	222.0	10.8	.70	43
7750	93.7	138.3	92.7	222.0	11.0	.67	42
8000	93.7	142.7	95.8	225.2	10.8	.67	42
8250	90.3	141.8	98.6	230.1	10.7	.70	41

AEROCHARGED 1997 POLARIS 700 RMK
350/360 MJ 9 PSI BOOST AV GAS

Data for 29.92 Inches Hg. 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .744
Vapor Pressure: .24 Barometer: 29.97

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
5500	72.2	75.6	59.1	147.1	11.4	.79	46
5750	84.4	92.4	49.5	169.7	15.7	.54	46
6000	93.4	106.4	65.4	190.9	13.4	.62	46
6250	100.0	119.1	72.3	205.2	13.0	.61	47
6500	104.3	129.1	77.8	213.6	12.6	.61	46
6750	107.7	138.4	82.9	223.8	12.4	.60	47
7000	107.2	142.9	82.5	229.1	12.8	.58	46
7250	111.3	153.6	100.3	238.9	10.9	.66	46
7500	112.9	161.2	102.7	242.9	10.9	.64	47
7750	112.7	166.3	99.2	248.8	11.5	.60	46
8000	110.5	168.3	94.2	255.6	12.5	.56	46
8250	103.8	163.1	99.3	260.8	12.1	.61	46

YAMAHA 600 SX

Last year, the Turbo Yamaha VMax600 tested in Vol. 6, no. 2 provided excellent performance at reasonable boost levels. The single pipe, cylinder reed inducted twin's strong crankshaft and connecting rods have proven durable as well, with some madmen like Greg Santry operating at very high boost levels, on high octane gas, for long periods of time. Stock, low RPM, monster torque levels are definitely easier on bottom ends than much lower torque and horsepower levels at high RPM.

The new 600SX seems even more ideal for turbocharging; reportedly it has even better crank/rod durability, which along with improved cylinder breathing with no increase in port timing allows this engine to make noticeably more power per pound of boost pressure than last year's engine.

It's as though Yamaha engineers designed the new digital ignition with the turbo crowd in mind; as the throttle is held wide open, ignition timing gradually retards. The result is brisk, responsive acceleration with the confidence inspiring knowledge that the longer you run at full throttle, the timing will increasingly relax to offset the coolant and combustion chamber heat buildup. Hill climbers and river runners (like Ottawan Richard Hiley, whose sled is featured here) who run full throttle for minutes at a time should appreciate this new ignition.

The new 600SX turbo system is less expensive, because it utilizes the stock single pipe to feed exhaust to the Aerocharger instead of the custom replacement single as used by the Vmax600 and 670 MX-Z.

Also, adjustable power jets are used on this model for the first time, smaller main jets result, and crisp but safe low end tuning is easier to obtain.

Note that 6 to 10 psi boost levels is fine for 92+ octane pump gas to 100LL AV gas, respectively.

Operating at ultra-high boost levels from 13-16 psi range requires fresh race gas of the highest possible octane, and puts the 600SX's #128 Aerocharger on the edge of overspeed at sea level. High altitude riders must not run these ballistic boost levels--the thin air may contribute to turbo overspeed and damage.

Also, the INTERCOOLED final run was with a custom intercooler built by Maynard Troyer for his own turbocharged 600SX. With the intercooler mounted between the turbo and airbox, and 80 mph, 45 degree air blowing on it, the highly compressed intake charge temperature was reduced from 216 to 132 degrees F!.

AEROCHARGED 1997 YAMAHA 600SX
157.5 MJ 6 PSI BOOST PUMP GAS

Data for 29.92 Inches Hg. 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .735
Vapor Pressure: .19 Barometer: 29.97

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
6000	66.7	76.2	66.2	158.3	11.0	.87	47
6250	69.3	82.5	65.7	164.9	11.5	.80	48
6500	72.7	90.0	67.9	171.3	11.6	.75	48
6750	75.3	96.8	71.1	176.1	11.4	.73	49
7000	83.0	110.6	76.0	186.9	11.3	.69	49
7250	86.2	119.0	78.9	196.0	11.4	.66	49
7500	90.0	128.5	80.3	203.7	11.6	.62	47
7750	90.6	133.7	85.8	205.3	11.0	.64	47
8000	89.5	136.3	86.4	207.4	11.0	.63	47
8250	83.7	131.5	90.1	208.3	10.6	.69	47

AEROCHARGED 1997 YAMAHA 600SX
157.5 MJ 7.5 PSI BOOST PUMP GAS

Data for 29.92 Inches Hg. 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .735
Vapor Pressure: .19 Barometer: 29.97

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
6000	74.8	85.5	63.9	177.8	12.8	.75	49
6250	78.4	93.1	66.4	186.7	12.9	.71	50
6500	83.2	103.0	88.2	195.7	10.2	.86	50
6750	88.2	113.4	95.7	202.1	9.7	.84	49
7000	91.8	122.4	84.6	209.3	11.4	.69	49
7250	94.6	130.6	91.1	216.9	10.9	.70	49
7500	99.8	142.5	99.7	228.6	10.5	.70	49
7750	98.1	144.8	101.2	230.9	10.5	.70	49
8000	92.2	140.4	103.7	235.1	10.4	.74	49
8250	83.1	130.5	105.8	233.8	10.1	.81	49

AEROCHARGED 1997 YAMAHA 600SX
152.5 MJ 9.5 PSI BOOST AV GAS

Data for 29.92 Inches Hg. 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .735
Vapor Pressure: .19
Barometer: 29.98

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
6000	79.1	90.4	111.8	198.0	8.1		51
6250	84.2	100.2	111.4	208.0	8.6		51
6500	87.3	108.0	113.1	214.7	8.7	1.05	51
6750	92.3	118.6	88.5	225.3	11.7	.75	50
7000	95.5	127.3	89.7	233.5	12.0	.70	50
7250	99.7	137.6	94.9	242.6	11.7	.69	49
7500	103.2	147.4	101.2	252.0	11.4	.69	49
7750	104.1	153.6	104.7	257.5	11.3	.68	49
8000	99.8	152.0	104.7	260.1	11.4	.69	49
8250	84.9	133.4	110.3	257.1	10.7	.83	48

AEROCHARGED 1997 YAMAHA 600SX
15.5 PSI BOOST 114 OCTANE
(SHORT SEA LEVEL RUNS)

Data for 29.92 Inches Hg. 60 F dry air
Test: 200 RPM/Sec Acceleration
Fuel Specific Gravity: .743
Vapor Pressure: .33
Barometer: 30.04

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
6250	95.1	113.2	100.8	247.2	11.3	.89	46
6500	100.3	124.1	98.7	259.8	12.1	.80	47
6750	103.6	133.1	93.8	270.0	13.2	.70	47
7000	111.1	148.1	110.6	281.6	11.7	.75	47
7250	116.5	160.8	111.7	290.2	11.9	.69	47
7500	119.4	170.5	115.5	296.7	11.8	.68	47
7750	121.8	179.7	116.8	306.9	12.1	.65	47
8000	121.1	184.5	115.1	312.3	12.5	.62	46
8250	118.0	185.4	122.8	313.9	11.7	.66	47

AEROCHARGED 1997 YAMAHA 600SX
16 PSI BOOST 2.25 CUSTOM INTERCOOLER
114 OCTANE (SHORT SEA LEVEL RUNS)

Data for 29.92 Inches Hg. 60 F dry air
Test: 200 RPM/Sec Acceleration
Fuel Specific Gravity: .743
Vapor Pressure: .33
Barometer: 30.05

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
6500	107.4	132.9	92.1	266.2	13.3	.69	43
6750	112.6	144.7	98.3	278.3	13.0	.68	43
7000	116.1	154.7	109.9	286.9	12.0	.71	43
7250	123.3	170.2	113.8	294.0	11.9	.67	43
7500	126.9	181.2	116.4	304.5	12.0	.64	42
7750	131.0	193.3	116.5	308.3	12.2	.60	43
8000	132.3	201.5	114.8	314.1	12.6	.57	45
8250	129.6	203.6	117.2	318.4	12.5	.58	44
8500	120.3	194.7	114.7	323.5	13.0	.59	44

DETO!

The Cellar Dweller

Kevin Cameron

I first encountered detonation back in 1966, and I didn't know what it was. Fortunately for me, it was a light case, and the only symptoms were small holes being eaten into the edges of a motorcycle cylinder head's squish band.

Later, pushing to higher compression, I would generate my share of pistons that were detonated away until their rings hung out into empty space. I would learn to look out for the tiny, ash- gray flake of quenched aluminum on a spark plug, or in water-cooled engines, for the sudden and otherwise unexplained rise in engine temperature. And I would still be curious about those dusty holes, eroded into cylinder heads.

Books will tell you what Harry Ricardo learned back in 1918; that detonation is not the same as preignition. Preignition is lighting of the charge before the spark, by some hot object in the combustion chamber - usually the overheated center-wire of a spark plug whose heat range was too hot for the application. Preignition soon provokes detonation, so the confusion is understandable.

Detonation, by contrast, is self-ignition of some of the last parts of the charge to burn - the so-called "end-gas" out at the edges of the combustion chamber - after the spark has already ignited and mostly burned the charge. This self-igniting end-gas does not then burn normally, as a flame front spread by turbulence at the usual speed of a few tens of feet per second. This gas burns at the local speed of sound, which is very high because the temperature is high. This form of combustion, called detonation, forms a shock front, a sudden jump up in pressure that propagates at thousands of feet per second.

When it hits parts, it hits hard. If we hear it at all, it is as a high, dry, irregular clicking, not unlike the reverberating sound of rocks struck together under water. Detonation's pressure front can damage bearings by its hammering shock, but the real problem is what it does to an engine's natural, internal insulation.

In any situation in which gases move next to solid surfaces, there is a layer of significant thickness that remains largely stagnant because it is attracted to the surface. In internal combustion engines, this boundary layer quite effectively shields the engine's metal internal surfaces from direct contact with combustion gas, keeping them cooler than they would otherwise be.

When detonation begins - even light deto - this boundary layer is scoured off by the impacting shock waves, and heat transfer from hot gas to cool metal accelerates. In only a very few detonating cycles, piston temperatures rise dramatically, and the rest of the parts exposed to combustion gas aren't far behind.

What is strange to many people is that as this happens, exhaust gas temperature falls. This seems odd because people associate detonation with heat, and heat with failure. But the fact is that as you jet an engine down, its exhaust temperature peaks, not when mixture becomes lean (that is, too little fuel to react all the oxygen in the air charge), but when mixture is chemically perfect. Exhaust gas temperature falls when detonation begins because the engine's internal insulation is destroyed; that being so, some heat that would otherwise go out the exhaust is now being diverted into the piston, head, and cylinder walls. Because those parts are getting hotter, the exhaust gas becomes colder.

Those of us who began racing before water cooling arrived tend to think that engines get hotter the more we jet them down. With air cooling, this seems to be true, but isn't. The engine runs cool when it's rich because the extra fuel reduces peak flame temperature, and as we jet down towards chemically-correct mixture, the engine runs hotter and hotter. Often, in a modified engine with high compression, detonation begins even before we reach correct mixture and peak flame temperature. Then the engine really heats up. This leaves us with the idea that leaning down the mixture raises engine temperature, in a straight-line relationship.

Now we know, from our experiences with water-cooled engines, that power, engine temperature, and exhaust gas temperature all rise as we jet down - until we go beyond chemically-correct mixture. When we do, power, engine temperature, and exhaust gas temperature all begin to fall again. We couldn't see this before, with air cooling, because the power we were making was overwhelming the engine's cooling

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ability. But it makes perfect sense because heat release in combustion depends upon finding enough oxygen so that each and every hydrogen and carbon in the fuel is completely reacted to form water and carbon dioxide. Any fuel left over is potential chemical energy unreleased - which is why running rich makes less power. Any oxygens left over are likewise potential chemical energy unreleased - which is why running lean makes less power. On any well-cooled engine that is not detonating, you can jet down until it starts to slow down.

Now back to detonation. The above explanation is the common one, but it leaves important questions unanswered. For example, why does detonating combustion travel at the local speed of sound, and not at normal burning speed? Why does the end-gas auto-ignite, rather than simply wait there like a stand of trees in the path of a forest fire? Understanding how this comes about helps to understand how the variables that affect detonation generate their effects - and it helps to fend off this phenomenon that sets the upper limits on performance.

There are two basic forms of combustion, deflagration and detonation. In deflagration, the propagation of combustion is carried out by simple convection; the hot combustion gas heats what is ahead of it, raising its temperature to the ignition point. Because this process of heating what lies ahead takes time, it is relatively slow. The burning of a quiescent gasoline-air vapor is in fact slow - only a foot or so per second. Combustion in an engine cylinder is much faster than this because of turbulence, which so wrinkles the flame front that its area becomes hugely enlarged. This area, multiplied times the slow quiescent combustion speed, computes out to a very large volume combustion rate.

Detonation is a different animal, and not all gaseous mixtures will support detonation. It is a form of combustion in which the unburned material is heated to ignition at least partly by shock compression, as the detonation wave moves at the local speed of sound through the medium. This has to happen very quickly, so fuels with simple molecules or those with low stability lend themselves to this form of combustion.

Now how does the end-gas ignite by itself? It does so when its temperature is raised by any combination of effects to some critical value in the range 900-1000 degrees F.

In a running engine, air is drawn in at some ambient temperature, and this air then begins to pick up heat from the hot internal engine surfaces it contacts. Finally it enters the actual cylinder, where it is further heated by even hotter surfaces. Trapped there, it is heated again by the process of compression.

In this heating process, some little-discussed chemical reactions begin to occur in the fuel. Called pre-flame reactions, these take the form of slow, partial break-down of the least durable types of fuel molecule. Fuel hydrocarbons have three basic forms; straight carbon chains, branched chains, and ring structures. Temperature is a measure of average molecular activity, but there are always some gas molecules moving significantly faster than the others. These faster-moving molecules hit and break some of the less-durable fuel molecules, dislodging some of their more weakly-bonded hydrogen atoms. This released hydrogen is very reactive (normally hydrogens travel in bonded pairs, but this is atomic hydrogen) and instantly pairs with an oxygen from the air to form what is called a radical, a chemical fragment that is highly reactive because it contains an unpaired electron. Its attraction for the missing electron is so great that it can snap one out of other chemical species it happens to collide with, thereby breaking it down as well.

At some point in the compression stroke, the spark ignites the mixture and combustion begins. The burned gases, being very hot, expand against the still unburned charge, compressing it outward into the squish band. This compression rapidly heats the unburned charge even more, accelerating the pre-flame reactions in it. As a rule of thumb, the rate of chemical reactions doubles every seventeen degrees F. All this while, the population of reactive molecular fragments - radicals - is increasing in the unburned end-gas. If this process of heating takes long enough, and reaches a temperature high enough, this population of radicals becomes great enough that its own reaction rate - one radical creating more and more through further reactions - accelerates into outright combustion. This is auto-ignition.

Now why does this heated, chemically-changed end-gas detonate instead of simply burning? The fuel in the end-gas is no longer ordinary gasoline. The pre-flame reactions that have taken place in it have changed it into a violent explosive - much like a mixture of hydrogen and air, or acetylene and oxygen. It is in a hair-trigger state, being filled with reactive fragments from pre-flame reactions. When it auto-ignites spontaneously, combustion accelerates almost instantly because the material is so easily ignited now. The combustion front accelerates to the

DETO!

Kevin Cameron
The Cellar Dweller

mixture of hydrogen and air, or acetylene and oxygen. It is in a hair-trigger state, being filled with reactive fragments from pre-flame reactions. When it auto-ignites spontaneously, combustion accelerates almost instantly because the material is so easily ignited now. The combustion front accelerates to the local speed of sound, igniting the material it passes through simply by suddenly raising its temperature, through the shock wave it has now become.

STOPPING THE SHOW

Anything that contributes to lowering the temperature that the end-gas reaches will make detonation less likely. Anything that slows the process of conversion from normal gasoline into a sensitive explosive, will make detonation less likely. Anything that speeds up combustion, so that it is completed before the conditions needed for detonation can develop fully, will make deto less likely.

Therefore the following will work;
(1) Lower intake temperature

(2) Lower throttle position, lower volumetric efficiency, or reduced turbo boost - the less mixture that enters the cylinder, the less it is heated by compression.

(3) Lower intake pipe, crankcase, and/or cylinder, piston, or head temperatures. This yearÕs Yamaha 250 road race engine, for instance, has a copper cylinder head insert to conduct combustion heat away faster, resulting in a lower combustion chamber surface temperature.

(4) Lower compression ratio. The less you squeeze it, the less it is heated.

(5) A more breakdown-resistant fuel, such as toluene or iso-octane. If straight-chain molecules are not present, the fuel will not be broken down so rapidly by pre-flame reactions.

(6) A negative catalyst - something that will either pin down active radicals or convert them into something harmless. Tetraethyl lead, MMT, or other anti-knock compounds are the medicine.

(7) Retarded timing - shortens the time during which pro-knock reactions can take place

(8) In-cylinder turbulence or anything else that will speed up combustion (faster-burning fuel such as benzene). This works by completing combustion before the time-bomb of pre-flame reactions cooks long enough to cause auto-ignition and deto.

(9) Higher engine rpm - This simply shortens the time during which mixture is held at high temp. In Honda experiments in the 1960s, they found that an engine's octane requirements began to decrease steadily over 12,000 rpm, and were under 60 octane up near 20,000. In a more accessible example, note that engines knock when they are 'lugged' - run at low rpm, wide-open throttle - and stop knocking promptly when you shift down a gear and let the engine rev up more. This stops deto by not allowing enough time for the reactions that cause it.

(10) Redesigning troublesome exhaust pipes. Some pipes give great numbers on the dyno, but can't be used because they cause seizures. They either simply over-charge the engine in some narrow rpm band (pushing it into detonation just as too much turbo boost would do), or back-pump mixture from the header pipe that has picked up too much heat (this is why nobody heat-wraps header pipes any more).

(11) Avoiding excessive back-pressure. Exhaust pipes always create back pressure, but the more there is, the higher the fraction of hot exhaust gas that will be unable to leave the cylinder during exhaust. Its heat, added to the fresh charge that next enters the cylinder, may push the engine over the line into detonation. Sometimes a one or two millimeter reduction in tailpipe ID will get you a couple of extra horsepower, but it may also push enough extra heat into the charge to make the engine detonate after a few seconds.

The number of ways of playing footsie with detonation is endless, but nothing works every time. This guarantees that we will never be bored, and will never run out of seized pistons.

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