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DYNOTECH

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1995 Arctic Cat 800ZRT

stock evaluation

ZRT 800 cc L/C Triple
Carburetion: (3) Mikuni VM 38
Weight: 597 lbs (w/ 3 gals. gas)

This is essentially a 900 T-Cat engine with a smaller bore diameter. The carbs, reeds, airbox, ignition, crankcase, crankshaft, combustion chamber, o-rings, and even pipes and canister are identical (same part #). Only the pistons and bore size are different.

The port timing and dimensions are also identical; the ZRT exhaust ports are the same height and width as the T-Cat's, but noticably more "squared off" at the top, giving those ports a bit more area. Also, the identical exhaust port width would be effectively wider on the 800, when considered as a percentage of bore diameter.

For our dyno evaluation, 420 main jets were used in place of the factory 450's to correctly compensate for the approximately 60 degree F air temperature of the day. In typical Cat fashion, the BSFC was a low octane safe spec in the mid .70's. This would be fine for those who run questionable gas for long distances at WOT. It also was rich enough that the engine blubbered just a bit through the midrange, WOT section of the power curve.

93 octane unleaded gasoline was used for the test. The airflow meter was not utilized. When we do our comprehensive one-step-at-a-time performance improvement exercise on this engine, we'll analyze airflow.

1995 800 ZRT
420 MJ--Q0 NJ

Data for 29.92 inches Hg, 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .746
Vapor Pressure: .32
Barometer: 29.97

RPM	CBT	CBHP	FUEL	BSFC	CAT
6500	75.2	93.1	84.0	.91	56
6750	72.5	93.2	89.4	.96	56
7000	76.7	102.2	92.7	.91	56
7250	80.2	110.7	96.3	.87	56
7500	86.5	123.5	97.4	.79	56
7750	89.5	132.1	100.0	.76	56
8000	94.6	144.1	104.3	.73	56
8250	93.1	146.2	107.5	.74	56
8500	83.1	134.5	108.7	.81	56

The D&D Cycles guys had received their first production ZRT just prior to the Hay Days grass race in September, and they quickly did their standard 900 race porting job on the engine and shortened the pipes with the idea of racing it in 800 improved stock class. Unfortunately, porting that has worked so well on the larger bore engines wasn't very effective on the 800. Power was disappointing, so more R&D had to be done before it could be competitive.

The point here is, modifications that have worked so well on the 900 and 1000 engines won't necessarily be optimum for the smaller bore [illegible] doing some one-step-at-a-time perfor[illegible] on the 800, including pipes, re[illegible]ld be good for the casual trail [illegible]he 800 improved stock racer[illegible]re ultimate horsepower may [illegible]ut now and get it over with. Th[illegible]ring the cylinders is that 1000cc pist[illegible]ildcat) cost about the same as 900cc pistons.

To reduce the fuel flow, we elected to use our Magnehelic gauge (which reads out in inches of water pressure) connected to the vent hoses of the ZRT carbs. As we know from the article in Vol 4 #3, "Effects of Underhood Pressure on the V Max 4", very subtle float bowl pressure changes dramatically affect fuel flow.

At one inch of negative water pressure, we had fuel flow approximating that which would occur with 390 main jets (on Mikuni hex jets, fuel flow is directly proportional to the jet size). This gave us a BSFC of .65, which was safe for 92 octane gas for 15 seconds at WOT at 60 degrees F.

1995 800 ZRT
-1" Pressure Simulating 390 MJ--Q0 NJ

Data for 29.92 Inches Hg, 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .746
Vapor Pressure: .32
Barometer: 29.97

RPM	CBT	CBHP	FUEL	BSFC	CAT
6500	77.6	96.6	78.1	.82	59
6750	77.9	100.1	82.6	.83	59
7000	80.0	106.6	85.9	.81	59
7250	85.1	117.5	86.9	.75	59
7500	87.2	124.5	86.6	.70	57
7750	93.2	137.5	90.6	.66	57
8000	98.2	149.7	96.3	.65	57
8250	97.7	153.5	98.0	.64	57
8500	90.8	147.0	100.8	.69	57

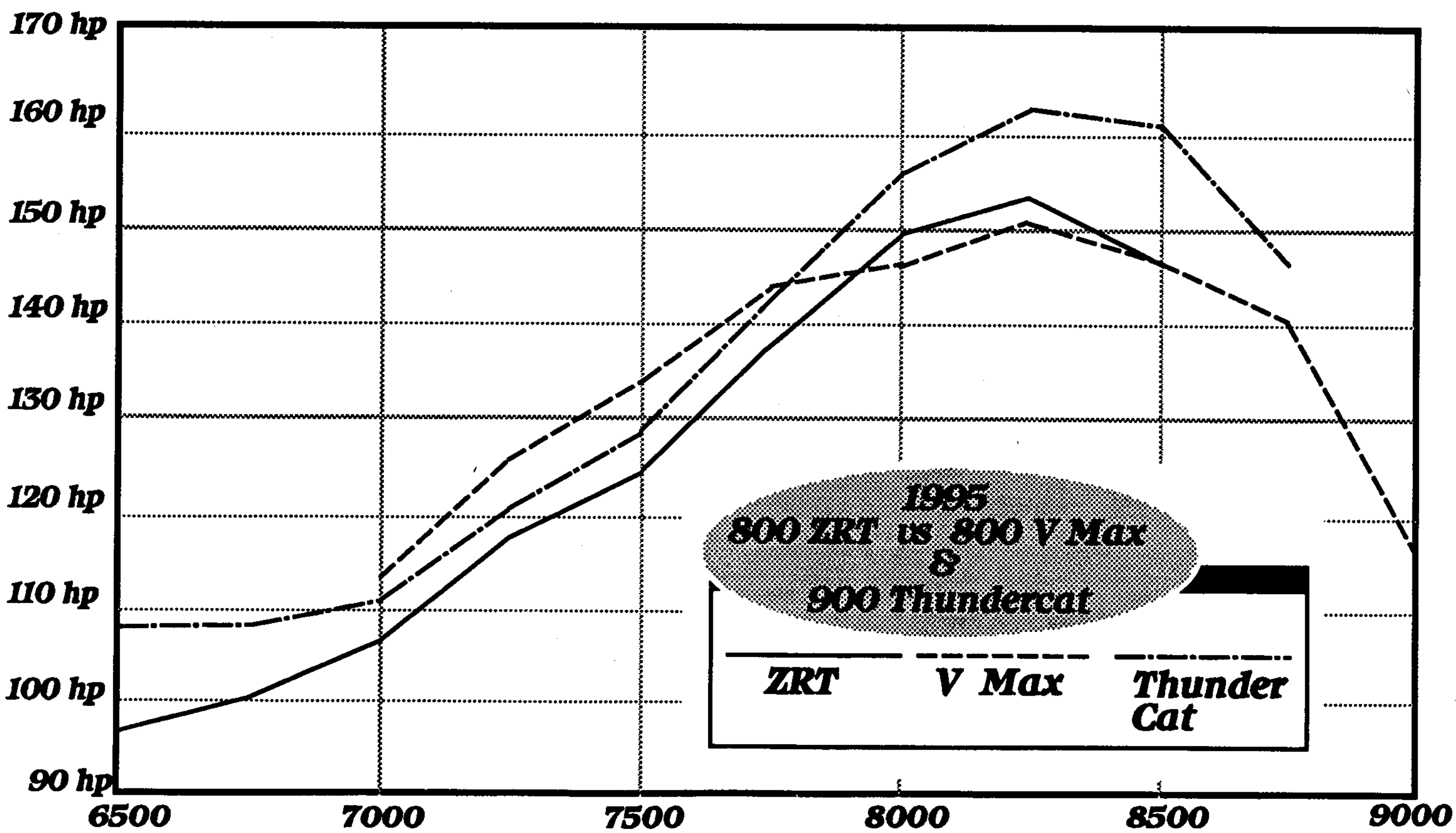
The minimum squish clearance listed for this engine in the ISR specs is .060". This one measured out at .075" out of the crate, as tested above. We removed .015" from the sealing surfaces of the heads, and with the 390 jets, the following data was generated by the engine. It was run at WOT for 15 seconds, with the pipes hot. The cool pipe horsepower peak (used for clutching by dragracers) is around 8100 RPM.

Those who desire to run lower octane gas and/or longer periods of time at WOT should probably not do this modification.

1995 800 ZRT HEADS MILLED .015" (.60 SQUISH)
-1" Pressure Simulating 390 MJ--Q0 NJ

Data for 29.92 Inches Hg, 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .745
Vapor Pressure: .31
Barometer: 29.96

RPM	CBT	CBHP	FUEL	BSFC	CAT
7000	78.9	105.2	75.5	.72	56
7250	81.7	112.8	82.0	.73	57
7500	86.9	124.1	88.3	.71	55
7750	90.3	133.2	88.6	.67	57
8000	95.8	145.9	94.5	.65	57
8250	99.1	155.7	101.8	.66	57
8500	96.3	155.9	102.4	.66	56
8750	82.8	137.9	105.6	.77	57



1994 ski doo Formula Z

TEST EVALUATION

I won't call the evaluation of two aftermarket pipe(s) a "shootout", but at the time of the test that is all we had available.

We would have waited until the new Jaws and Decker pipes were available, but the opportunity arose to test the pipes we had received when Bob Calpeter brought his Formula Z in for tuning. We'll publish an update when the other pipes are tested.

We tried rolling the RV timing both ways from stock, and during our test session, the stock factory setting was optimum for these pipes as well as the two single pipes we tried.

300 main jets correctly and safely compensated for the 75 degree CAT that we had at the time of the test.

1994 SKI DOO FORMULA Z
300 MJ--AA2--STOCK PIPE 82 dB

Data for 29.92 inches Hg, 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .710
Vapor Pressure: .58
Barometer: 30.05

RPM	CBT	CBHP	FUEL	BSFC	CAT
6000	60.4	69.0	45.5	.68	74
6250	61.7	73.4	57.6	.81	74
6500	60.9	75.4	60.4	.83	75
6750	61.5	79.0	64.3	.84	75
7000	63.7	84.9	68.7	.84	74
7250	65.5	90.4	71.0	.81	75
7500	66.8	95.4	68.5	.74	75
7750	66.3	97.8	72.2	.76	72
8000	57.5	87.6	73.1	.87	75
8250	35.3	55.5	70.5	1.32	75
8500	30.8	49.8	70.2	1.47	75

Installing the FAST Fat Boy replacement single pipe gave us 2-3 more ft/lb of torque and 3-4 more CBHP at the stock operating speed. Also, we registered slightly more noise due to the lack of the factory insulation on the tuned pipe.

1994 SKI DOO FORMULA Z
300 MJ--AA2--FATBOY SINGLE PIPE 84dB

Data for 29.92 inches Hg, 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .710
Vapor Pressure: .58
Barometer: 30.05

RPM	CBT	CBHP	FUEL	BSFC	CAT
6000	60.5	69.1	51.2	.77	75
6250	61.7	73.4	56.7	.80	75
6500	62.6	77.5	59.1	.79	75
6750	62.7	80.6	64.4	.83	75
7000	62.9	83.8	66.9	.83	76
7250	65.5	90.4	68.4	.78	75
7500	68.9	98.4	71.7	.75	76
7750	68.6	101.2	71.3	.73	74
8000	64.3	97.9	72.0	.76	76
8250	43.2	67.9	75.1	1.15	75

Next, we tested the Aarrow Twin pipes designed by Mike Weinandt. These are blown pipes, with a plateau of horsepower from 8000-8500 RPM, peaking typically at 8250. The cannister exhaust exited out the stock outlet, and gave us a reading of 94dB.

1994 SKI DOO FORMULA Z
300 MJ--AA2--AAROW TWIN PIPES 94 dB

Data for 29.92 inches Hg, 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .710
Vapor Pressure: .58
Barometer: 30.07

RPM	CBT	CBHP	FUEL	BSFC	CAT
6000	61.8	70.6	57.4	.84	74
6250	63.1	75.1	63.6	.87	74
6500	63.4	78.5	68.0	.89	75
6750	63.9	82.1	70.1	.88	74
7000	64.3	85.7	69.4	.84	76
7250	63.3	87.4	71.8	.85	75
7500	60.9	87.0	71.4	.85	75
7750	63.4	93.6	70.6	.78	75
8000	67.0	102.1	71.0	.72	75
8250	67.1	105.4	75.2	.74	74
8500	62.7	101.5	73.7	.75	75
8750	41.7	69.5	80.5	1.20	74

1995 Polaris 440 XCR

Carburetion: (2) VM34SS Slide
Bore & Stroke (mm): 68.25/60
Cooling Type: Liquid
Weight:488 lbs
w/3gals. gas

This year's XCR 440 has smaller 34mm VM Mikuni carbs to feed air/fuel mixture to the nickasil bored piston port twin. The single pipe is tuned differently as well.

When we tested the '94 XCR 440, the pipe needed to be unusually hot to perform well on the dyno. Last year's engine exhibited unusual midrange instability, or "surginess", on the dyno when the pipe was less than smoking hot. This type of midrange surging, (in which the automatic servo control on the waterbrake has to fight to keep the acceleration rate constant) is typically caused by excessive transfer port timing, or needle jets that are too small. On the '94, we would guess that the port timing was the culprit.

That '94 XCR's owner, Sean Ray, found that he needed to run very lean, 100 octane jetting to keep the pipe hot during Snowcross competition. The '95 440 exhibits none of that type of tuning fickleness.

Whether the carbs were tuned lean or rich, or the pipe was hot or cool, the new engine accelerated on the dyno without a hitch.

During this test session, which was done with 93 octane pump gas, we had the baffle in and out a few times, with no change in horsepower that couldn't be accomplished with a jet change and the stock box. The foam removal was equivalent to reducing the main jets three sizes. All test data is shown with the airbox stock.

Additionally, it is interesting to compare this with the Indy 400/ 440 trailport bigbore that we tested a few years ago in Vol 1 #4. That data follows the pipe data.

Initially, we replaced the stock 290 main jets with 260's to safely compensate for the 50 degree F air (CAT) of the test session. We won't include the airflow data here because the large "drain" holes in the bottom cause the readings to be low.

STOCK 1995 POLARIS INDY 440 XCR
260 MJ

Data for 29.92 inches Hg, 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .745
Vapor Pressure: .31 Barometer: 30.10

RPM	CBT	CBHP	FUEL	BSFC	CAT
6000	35.6	40.7	37.4	.92	52
6250	37.9	45.1	41.9	.93	53
6500	39.0	48.3	44.0	.91	53
6750	41.3	53.1	48.3	.91	52
7000	44.0	58.6	48.1	.82	50
7250	46.7	64.5	50.3	.78	52
7500	49.1	70.1	52.6	.75	52
7750	51.8	76.4	55.0	.72	52
8000	50.1	76.3	59.5	.78	52
8250	46.9	73.7	58.2	.79	52
8500	39.8	64.4	59.9	.93	52

The BSFC with the standard jets was an ultra safe .75, so we installed 230 mains. This raised horsepower, and lowered the BSFC to .65 lb/ hphr. This should be a safe trail jet spec for sea level 50 degree F air.

STOCK 1995 POLARIS INDY 440 XCR
230 MJ

Data for 29.92 inches Hg, 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .745
Vapor Pressure: .31
Barometer: 30.10

RPM	CBT	CBHP	FUEL	BSFC	CAT
6250	33.5	39.9	35.5	.89	52
6500	35.5	43.9	36.4	.83	52
6750	39.3	50.5	41.4	.82	53
7000	41.4	55.2	40.8	.74	53
7250	45.1	62.3	44.2	.71	52
7500	46.3	66.1	46.3	.70	52
7750	48.8	72.0	46.9	.65	52
8000	51.3	78.1	49.2	.63	54
8250	49.1	77.1	50.9	.66	53
8500	45.6	73.8	54.6	.74	53

→

1995 Polaris 440 XCR CONTINUED

Racers will appreciate this maximum horsepower jet spec, which occured with 200 mains at this temperature. Note that the horsepower peak shifted upwards a bit, due to the pipe being hotter.

The following is a repeat of the 400/440 Big Bore tested in Vol. 1 #5, 1989 (!) The engine is shown with stock jetting and pipes, and 35.2 mm carbs. It's an interesting footnote to our 1995 440XCR evaluation.

STOCK 1995 POLARIS INDY 440 XCR 200 MJ

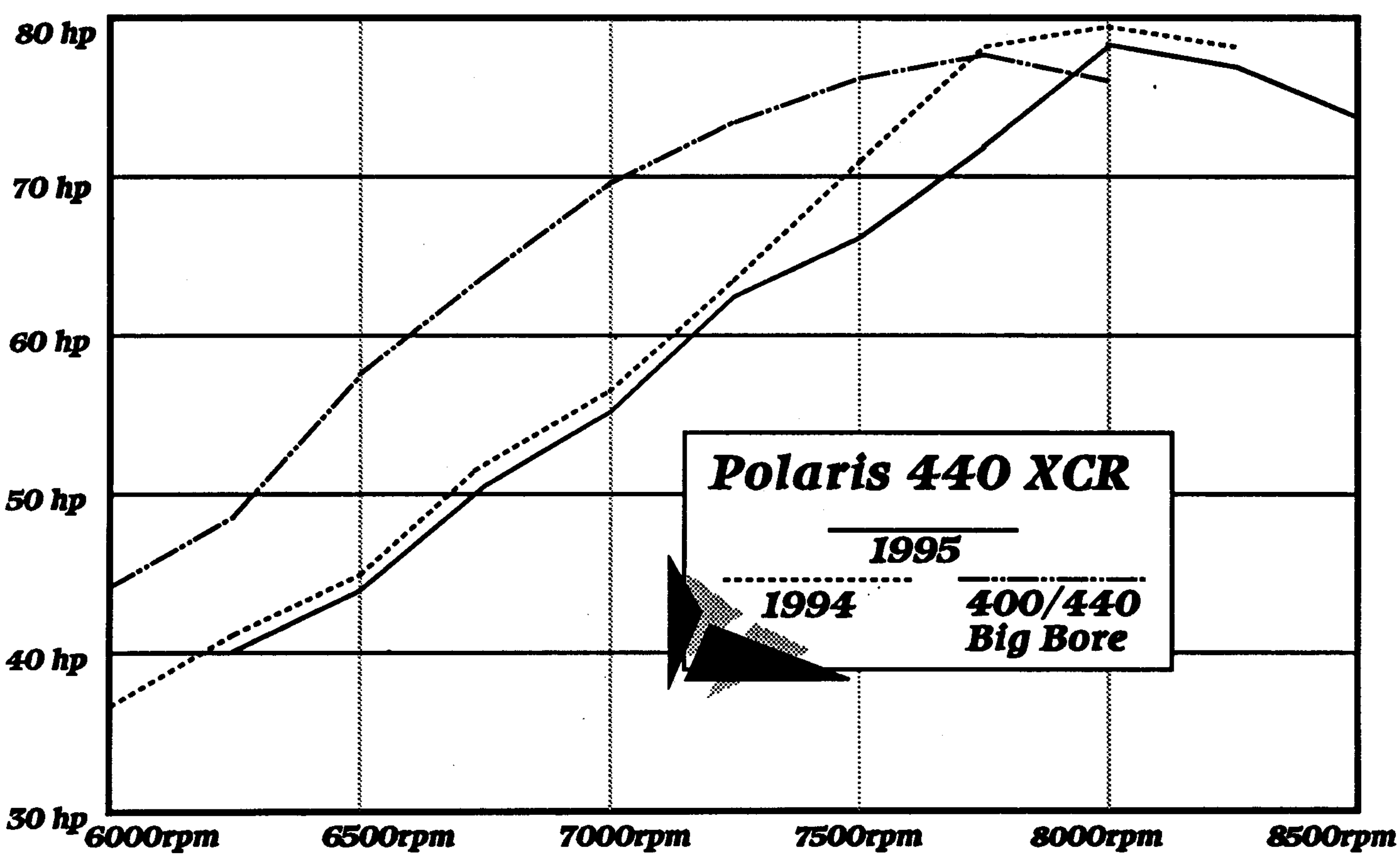
Data for 29.92 inches Hg, 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .745
Vapor Pressure: .31
Barometer: 30.10

RPM	CBT	CBHP	FUEL	BSFC	CAT
6000	34.7	39.6	31.3	.79	53
6250	37.6	44.7	34.0	.76	54
6500	40.1	49.6	34.7	.70	55
6750	42.3	54.4	35.9	.66	55
7000	45.8	61.0	37.8	.62	53
7250	48.2	66.5	40.6	.61	53
7500	48.8	69.7	41.8	.60	53
7750	53.1	78.4	43.1	.55	53
8000	52.6	80.1	44.1	.55	53
8250	51.1	80.3	45.0	.56	54
8500	45.5	73.6	47.8	.65	53

BIG BORE INDY 400/440

Data for 29.92 inches Hg, 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .734
Vapor Pressure: .10
Barometer: 30.31

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
6000	38.7	44.2	37.6	96.1	11.7	.81	31
6250	40.7	48.4	39.8	102.8	11.9	.79	32
6500	46.4	57.4	45.9	113.9	11.4	.77	32
6750	49.4	63.7	48.7	120.5	11.4	.73	31
7000	52.4	69.8	49.8	126.8	11.7	.68	34
7250	53.0	73.2	51.0	130.5	11 8	.67	34
7500	53.4	76.3	49.3	134.1	12 5	.62	35
7750	52.8	77.9	50.6	135.5	12.3	.62	35
8000	49.9	76.0	51.1	136.8	12.3	.64	34



Ski-Doo MX-Z Performance Hop Up To MX-ZX

CONVERSION FROM MX Z TO MX ZX SPECIFICATIONS

Bob Calpeter brought his SkiDoo MX-Z 440 to the C&H Dyno to perform, one step at a time, the factory tune-up.

The MX-ZX conversion consists of a different rotary valve and more radically ported, higher performing cylinders. First, we established a pump gas stock baseline in MX-Z stock form, with the stock 280-290 main jets reduced to 230-240 to correctly compensate for the 75+ degree temperature (CAT) on the dyno that day.

1994 SKI DOO MXZ STOCK
235 MAIN JETS
Data for 29.92 Inches Hg, 60 F dry air
Test: 50 RPM/Sec Acceleration
Fuel Specific Gravity: .710
Vapor Pressure: .70
Barometer: 30.02

RPM	CBT	CBHP	FUEL	BSFC	CAT
5000	37.8	36.0	31.8	.92	77
5250	40.8	40.8	34.4	.88	77
5500	43.1	45.1	34.2	.79	76
5750	45.5	49.8	41.4	.87	76
6000	48.0	54.8	49.2	.93	77
6250	50.3	59.9	46.3	.80	76
6500	51.2	63.4	44.8	.74	77
6750	52.1	67.0	42.4	.66	77
7000	53.5	71.3	44.9	.66	76
7250	54.8	75.6	50.1	.69	76
7500	53.2	76.0	51.4	.70	76
7750	47.5	70.1	52.7	.78	76
8000	37.5	57.1	50.8	.93	77

The stock MX-Z rotary valve (number 504) timing is 132-52. The optional MX-ZX rotary valve (number 502) timing is a more radical 145-65. Installing first only the ZX rotary valve, the following test data resulted. Note that the ZX rotary valve made more horsepower from 5500 and higher, with minimal low RPM loss. This gave us a four CBHP increase on top end.

1994 SKI DOO MXZ
235 MAIN JETS--502 ROTARY VALVE
Data for 29.92 Inches Hg, 60 F dry air
Test: 50 RPM/Sec Acceleration
Fuel Specific Gravity: .710
Vapor Pressure: .75 Barometer: 30.03

RPM	CBT	CBHP	FUEL	BSFC	CAT
5000	37.0	35.2	30.3	.90	77
5250	39.8	39.8	32.5	.85	76
5500	43.8	45.9	38.9	.88	77
5750	46.9	51.3	44.0	.89	77
6000	49.9	57.0	45.0	.82	77
6250	52.6	62.6	44.0	.73	77
6500	53.9	66.7	45.8	.71	75
6750	54.9	70.6	44.1	.65	76
7000	57.1	76.1	46.4	.61	77
7250	57.8	79.8	48.5	.64	78
7500	54.8	78.3	50.7	.68	77
7750	44.7	66.0	51.4	.81	77
8000	32.1	48.9	51.6	1.11	77

Next, we installed the MX-ZX cylinders on the engine. Note that in the absence of the airflow meter, higher airflow is suggested by the identically jetted carbs delivering more fuel to the engine with the same RV timing. With the ZX cylinders, horsepower is reduced in the midrange, then is greatly increased at high RPM. The greatly increased hp is accompanied by a reduction in BSFC to the low .60's lb/ hphr range, on the edge of pump gas safety according to Bombardier.

1994 SKI DOO MXZ *ZX CYLINDERS*
235 MAIN JETS-- 502 ROTARY VALVE
Data for 29.92 Inches Hg, 60 F dry air
Test: 50 RPM/Sec Acceleration
Fuel Specific Gravity: .710
Vapor Pressure: .75 Barometer: 30.02

RPM	CBT	CBHP	FUEL	BSFC	CAT
5500	36.0	37.7	33.1	.92	77
5750	38.4	42.0	38.4	.96	78
6000	41.2	47.1	42.4	.90	78
6250	44.5	53.0	37.7	.74	78
6500	46.9	58.0	35.3	.63	76
6750	49.4	63.5	35.4	.58	76
7000	51.2	68.2	40.2	.62	78
7250	54.8	75.6	47.5	.66	77
7500	58.0	82.8	49.9	.63	77
7750	58.4	86.2	52.7	.64	78
8000	56.5	86.1	54.1	.66	77

I SCREWED UP SOME DATA

Dale Roes of D&D Cycles called to inform me that I had somehow goofed on the reporting of the final phase our T-Cat Performance Improvements in Vol 6 #1.

The final stock pipe 1000cc trail port horsepower had been 200+ CBHP, not 197.3 as is shown. The 197 CBHP data is with *stock reeds and reed cages reinstalled.* I looked through the last section of the 50+ dyno sheets and found the ones Dale was referring to. With the V-Force reed cages reinstalled, the following data was generated by the engine:

1994 1000 CC THUNDERCAT
39 MM CARBS--400 MJ
V-FORCE REEDS
Data for 29.92 Inches Hg, 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .742
Vapor Pressure: .60
Barometer: 29.62

RPM	CBT	CBHP	FUEL	BSFC	CAT
6250	96.0	114.2	84.8	.78	79
6500	100.5	124.4	86.0	.73	79
6750	104.7	134.6	93.8	.74	80
7000	107.8	143.7	100.5	.74	79
7250	109.1	150.6	108.0	.76	79
7500	113.5	162.1	113.9	.74	80
7750	118.7	175.2	105.7	.64	80
8000	123.3	187.8	111.1	.62	80
8250	125.0	196.4	112.6	.61	79
8500	124.4	201.3	112.5	.59	80
8750	118.7	197.8	112.8	.60	79
9000	110.0	188.5	110.1	.62	80

My apologies to the V-Force guys and to anyone who went out and purchased the aftermarket pipes (which were tested with the V-Force reeds) thinking that they were getting 8 horsepower.

POLARIS

According to Polaris, the long awaited 700 (cylinder reed?) engine won't be available "this calendar year". Might we see one at the Battle of Old Forge V?

BATTLE OF OLD FORGE V

Let's get ready to rumble (that's boxing announcer Michael Buffer's trademark line)! This will be the greatest ever--if we have snow on December 8. We're expecting to concentrate on the 800 and 600 class. Make your reservations now at Van Auken's Inne (315-369-3033).

BIG BOB SHOOTOUT

After last year's Battle of Old Forge IV, we had the second annual Big Bob Shootout in a secret field in the town of Webb. This one was the best. It's really fun when you get to make your own rules, adjusting them as you go to keep one up on the competition.

Our pal Craig Brinster came hunting for our turbo sleds again with the two-hundred-and- too-many horsepower Crank-Shop powered 1,000cc Ski Doo MX-Z. This was the same one he ran against us the previous year (see DynoTech Vol 5 #1 and Vol 8 #5 of American Snowmobiler).

This time, Craig had his track loaded with "grasshooks" to take advantage of the soft, lightly snow-covered turf that we had to run on that week during the Battle of Old Forge IV. Jerry Basset and I had taken turns test driving the MX-Z that day, and the grasshooked track made it leave the line like a Pro-Stocker. Out of the hole, our trail carbide-picked turbo sleds might be in trouble, especially in the 400 foot "strip" we selected later for the Big Bob Shootout.

My partner Greg Bennett, in a characteristic moment of brilliance, decided to wait until a cold front moved in on Saturday to hold the "event". At about four o'clock in the afternoon, Greg decided to begin the festivities. By then, the field had been transformed into a rock-hard frozen tundra that provided excellent bite for our trail carbides. "Unfortunately", Craig Brinster's broad spring steel grass hooks would now have a traction coefficient of an excited dog chasing a ball on a waxed hardwood floor.

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There was another entry to Big Bob Shootout II; Kuyahoora Denny Johnson, competing with his mod 670 Mach 1 two-stage nitrous drag sled, with a low profile speed track and ice picks. He would surely be a contender in 400 feet on the frozen tundra. In his not-so-humble banty-rooster manner, Greg Bennett invited Denny to join the fun.

I personally chose to observe the action from the sidelines, watching Greg doing solo warm-up passes on each of the six or so turbo sleds on display there, jumping from one to another like a kid whose Dad had just told him to try each one out and he could keep his favorite.

Out of principle, he intended to line up his turbocharged Mach 1 670 against the bottle-charged Kuyohoora Mach I. By now, a crowd of perhaps several hundred spectators had gathered, including some guys doing a documentary snowmobile film. Denny set his nitrous sled down in the midst of the curious crowd, and attempted to do a solo warm-up pass. As the mod Mach 1 was fired, the crowd wisely separated ahead of it, clearing a narrow-looking path. The automatic first stage of the nitrous system engaged as Denny whacked the throttle, and the crowd behind the sled was instantly showered with a black plume of frozen dirt and rocks as the Mach 1 rocketed out of the hole. Apparently, the second stage was applied early and proved too much for the drivetrain and/or engine, because at the 50 foot mark, we heard a loud snap followed by silence as the sled shuddered to a stop. A cloud of blue-green vapor wafted from beneath the hood of the mortally wounded Mach. The spectators who had been hit by the frozen shrapnel of the hole-shot cheered and laughed.

Greg Bennett then did more than a few drive-bys with the skis of his turbo Mach in the air--one hand on the controls and the other pointing and taunting like young Cassius Clay circling as Sonny Liston lay in a "mystery punch"-induced stupor on the canvas.

While all this was taking place, Craig Brinster was busy adding weight to his clutch in a vain effort to find traction for his 1000cc Crankshop MX-Z. He lowered the engagement to about 2000 RPM, and the shift point to about 7500 RPM where the engine made maybe 170 HP. Still, the grasshooks could only dance and spark on the now nearly bare frozen ground.

Greg was now riding the Turbo V-Max 600, and it was apparent that because of the excellent traction that the trail carbides provided, the middleweight turbo machines would be more than a match for the hopelessly tractionless and underreving MX-Z. In these conditions 400 feet was not enough distance for the spinning MX-Z to catch traction, and perhaps pull back on the 150 HP V-Max 600. Originally, Greg had hoped that the conditions would equalize the performance of the competitors. However, it was apparent that a track change on the MX-Z would be necessary to make an interesting contest of the Big Bob Shootout.

Rather than do all of that, Greg and Craig decided to do a few less than full throttle roll-ons, which looked to me more like a World Wrestling Federation Championship. At any rate, as darkness fell, the two sleds were absolutely side by side at the 400 ft mark--Craig's 1000cc engine groaning against the 100 gram weights while the shrieking turbo 600 changed pitch as it oscillated from full to part throttle and back again. Not many people noticed that. Those that did didn't seem to mind, either.

There were some post-race arguments by contestants and spectators regarding the true outcome of the "event".

It was good fun anyway, and will surely be again this year, as long as we get to make up the rules, and Craig leaves those grass-hooks in his track.

PIPE SHOOTOUTS COMING SOON
580ZR, 700ZR, more V-Max 600 singles, XCR600, XLT600, V-Max 800, XCR600, Storm 800?.

VERY INTERESTING
HTG's Rob Schooping recently built a 650 (690cc) Polaris pro-stock engine for a customer in the Midwest. A clone of many other engines that have been extemely competitive for Rob and others this season, this particular engine had been performing poorly for the customer, and detonating regularly on fresh racing gas. It had taken out enough pistons that resleeving was necessary.

The engine was shipped back to HTG, where it was freshened up and brought to the C&H Dyno for a checkup. On the dyno, the engine ran lazily,

FEEDBACK CONTINUED

with a barely audible lean-sounding mid-range sputter even with safe fuel flow. We didn't attempt a full dyno run.

A complete ignition system change (coils and CDI) was required to fix the problem, which apparently was erratic timing and firing of the coils under heavy load. Now, it ran cleanly like all the others--easily making 164 CBHP on a cold water seven second run.

The point is, whenever you have an engine that is driving you nuts with deto and/or poor performance, and everything checks out perfectly, it would be wise to borrow someone else's complete ignition system. Swap it and try again.

My good pal and ace Ferrari and Lamborghini mechanic Tony Selvaggio (they're always Italian, aren't they?) used to say calmly during such moments of mechanical mystery, "It's just a machine".

A MUST-TRY NEW PRODUCT

I've been using Loctite 599 Ultra Grey "import gasket maker" in place of conventional silicone sealer for every application. This very creamy silicone-based sealant doesn't become "crumbly" like conventional silicone when it dries--instead, it turns very elastic and rubbery. Also, it has withstood the heat generated at the exhaust flanges. Everyone who tries it here likes it.

YOU'VE GOT TO SEE IT TO BELIEVE IT!

If you flatlanders really want to see why mountain riding terrifies me, you should call Slice of Life Video Productions to purchase their $19.95 video of last year's Jackson Hole World Championship Hillclimb.

Snow King Mountain is said to be the most vertical ski-slope in the country, and the Slice-Of-Life film crew literally risked their lives to document these madmen racers scaling, or attempting to scale, this frightening course.

Those racers (most, actually) who fail to make it to the top of the mountain have to be "rescued" by rope-wielding cowboys who attempt to prevent the stalled sleds from bounding, end over end, back down the mountain. Sometimes they catch them before they fall; sometimes they don't.

It's a very professional, terrifying, and entertaining film. To reach Slice of Life call 1-800-USA-TAPE

I'VE BEEN CHALLENGED

John T. Cowie thinks that he can whip me in a 660 ft. dragrace. That's with him on a Schwinn 10-speed bicycle (with his equally spindley legs exerting 200 lb of force on the pedals) vs. my 220 lb. butt on a borrowed Honda 50 step-through.

We old timers recall how those awful little 1966 Hondas almost needed to be pushed to get going. That was the result of the centrifugal clutch engaging at about 500 RPM, where the 50cc engine made about 2 ft/lb of torque (.19 CBHP), most of which was lost to heating the slipping clutch initially. From there, the Honda 50 had to grunt through its "power" band, gradually increasing its acceleration rate as the revs climbed. Then, unfortunately, the things had to be shifted to the next gear. The too-wide ratio, three speed transmission was far from optimum for acceleration, but I contend it was far superior to the ten close-ratio speeds of John's rusty Schwinn.

John T. envisions himself hole-shotting me on the Honda 50 as it labors from 500 RPM engagement, enough so that the Honda's higher trap speed couldn't overcome the initial disadvantage.

What he doesn't realize is, that the Honda's centrifugal clutch can be overridden by holding the shifter down with your foot, opening the throttle wide like Dave Schultz does with his staged Pro Stock Suzuki (the Pro Stock bike uses a two-step electronic rev limiter while the Honda 50 uses ball-point pen valve springs to accomplish the same task). Then, the shifter can be released, tortuously engaging the clutch at 5 HP instead of .19 HP, resulting in either a spectacular foot and fender-dragging wheelie or, if the road surface is fresh tar, the rear wheel breaking loose, allowing the Honda engine to buzz near its power peak as the bike accelerates to catch up with the spinning rear wheel. In 1966, I always preferred that method for maximum acceleration when riding *borrowed* Honda 50's.

As long as I get to select the site of the contest, I will offer John T. a ten bicycle-length head start. But, after reading about my launching method, who will loan me their Honda 50?

The dB Explained...

Subscribers Tony Petriella of Dundee, Mi. and Don Elzinga of Waterford, Mi. responded to our request for further understanding of the decibel scale with the following excellent letters.

Dear Jim,
I'm writing in response to your request for more detailed information on sound levels. So, here it is; more than you ever wanted to know about sound:

Sound levels are specified in decibels (dB). This logarithmic scale is used because it approximates the way our ears respond. The formula for calculating dB is: $L = 20 \times \log_{10}(P/P_r)$

Where L is the sound level, P is the sound pressure being measured and P_r is 20 micropascals RMS (.00002 N/m^2; the threshold of human hearing at 1000 Hz) This formula gives the "linear weighted" sound level. Because the sensitivity of human hearing tapers off at low and high frequencies, the data are often modified by the use of the A-weighting curve, so that a sound level of 0 dBA, at any frequency, would be barely perceptible to a person with normal hearing. If you double the sound pressure, you get four times the sound power, and the level goes up about 6 dB. So an 83 dB noise has twice the sound power of an 80 dB noise, while doubling the sound pressure would give you 86 dB.

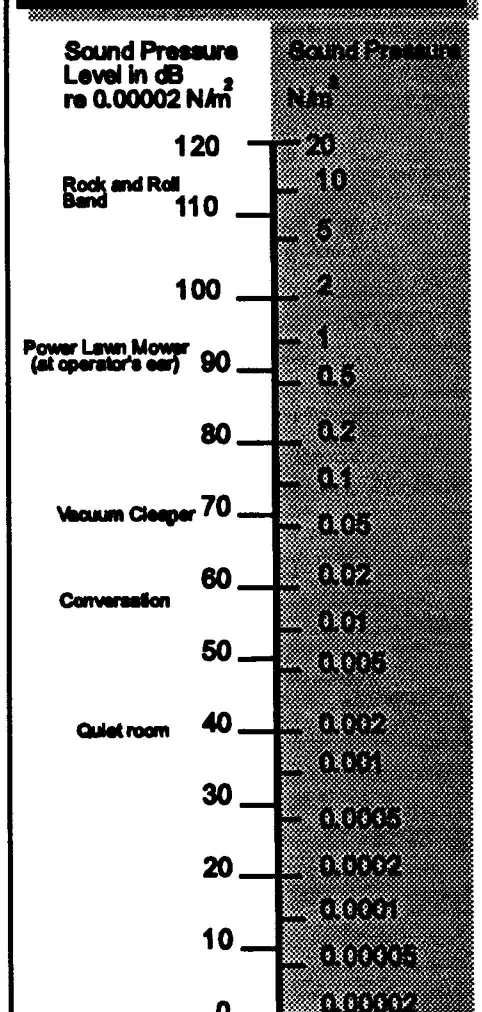
However, when you talk about loudness, you are talking about the perception of sound. It is generally agreed that an increase of 10 db corresponds to a perceived doubling of loudness. The smallest change that people can reliably pick out from sounds heard back-to-back is about 1 dB, and if the sounds are separated by a significant time delay, 3 dB is about the minimum noticeable difference. Of course, people's perception of sound falls under the heading of sound quality, which is a field of study unto itself. When you're dealing with subjects who might consider a guitar solo @ 100 dBA a pleasant experience, and a mosquito @ 10dBA extremely irritating, , it becomes difficult to put a precise number on level of annoyance! Unfortunately, snowmobiles cruising past your house after midnight usually fall into the latter category.

By the way, there are other reasons that aftermarket exhausts are noisy, besides ignorance on the part of the designers and/or customers. While it is certainly possible to make a muffler quiter without excessive backpressure, this requires a large increase in the volume. The larger muffler now has more surface area, made up of more flexible panels; these make excellent loudspeakers! It does little good to get the tailpipe noise down to 80 dBA if you've got 105 dBA radiating off the muffler shell. So the manufacturers go to thicker metal, double wall construction, etc., to make their machines quiet. Most aftermarket pipes use glasspacks instead of conventional mufflers. Besides requiring frequent repacking to maintain their performance, these have another disadvantage. They only really do a good job of attenuating the high frequencies from the engine. While that's good for the rider, it's the low frequencies that carry over long distances. To reduce the sound heard coming from that snowmobile trail over the hill, you need to attenuate them too; that's where the need for lots of muffler volume comes in. You mentioned in the last issue that some manufacturers' pipes leave little on the table in terms of horsepower gain; I suspect the same is true for noise. If the speed shops used the same criteria for noise and durability that the OEM's do, their pipes would make the same power (replacements for two or three-into-one excepted, of course), weigh as much and cost more due to the low production volumes. Who would buy them? So what can we do to keep our favorite trails from being closed due to homeowners' complaints? Publishing the noise levels of the pipes you test is a step in the right direction; keep up the good work.

Don Elzinga

Figure 1.1

Scale illustrating relationship between dB and sound pressure



Dear Jim and Debbie,

In your most recent issue of DYNOTECH you had summoned the assistance of readers to explain sound measurement of snowmobile exhaust systems utilizing the decibel scale. I hope I can be of some assistance.

Sound, in air, (we'll neglect the propagation of sound in other mediums, such as water, for our unfortunate water-crosser subscribers) is usually described in terms of oscillations of pressure above and below the ambient atmospheric pressure (in this case the words "sound" and "noise" can be used interchangably) caused by the combustion chamber explosion and concomitant expulsions out of the exhaust system outlet. These sound pressures can be measured. However, in order to measure these relatively large range of pressures with a scale incorporating a reasonable number of scale divisions, a logarithmic decibel scale was selected. By definition, the decibel is a dimensionless unit related to the logarithm of the ratio of a measured quantity to a reference quantity. Mathematically, the equation is given as: $L = 20 \log_{10} \frac{P}{P_0}$ dB

Where P_0 defines the reference sound pressure, usually given as .00002 Newton/meters squared for sound measurements in air. This reference number is an arbitrary pressure chosen because it was thought to approximate the normal threshold of human hearing at 1000 Hz.

However, instead of plugging numbers into the formula, grinding out calculations, and waiting for the dust to settle, if you refer to figure 1.1, the relationship between sound pressure in Newton/meter and the sound pressure level measured in dB (using the .00002 Newton/meter reference) is shown. This relationship illustrates the advantage of the dB scale rather than the wide range of direct pressure measurements. Note that any pressure range over which the pressure is doubled, is equivalent to six decibels whether at high or low levels. Thus sound level doubles at every six dB increase.

I hope this information can help you in some way.

Tony Petriella

TURBO V MAX 600

Low RPM operating speed. Small block Chevy-like connecting rods and crankshaft. Cylinder reed valves. These are just some of the features that make this engine so desirable for turbocharging.

Here are several dyno tests, recorded at three different dyno facilities, on the turbocharged V-Max 600. Ours is shown first--low boost, retarded timing, 92 octane pump gas. This year, we are recommending retarding ignition timing based upon testing we have done with Reichard Perfomance Center's programmable CDI. RPC's Jeff Simon sent us a CDI and a shoe-box full of computer chips, which were programmed with various degrees of timing.

We determined that three degrees less than stock timing was optimum at peak power on pump gas. This can be accomplished by either purchasing the RPC CDI with their turbo chip (stock timing in the low RPM range, then three degrees less at the power peak and beyond), or using a V-Max 500 CDI (two degrees less at the peak), or moving the ignition pickup by slotting the holddown screw holes to reduce timing everywhere.

Engine cooling is another issue that needs to be addressed. The 1995 V-Max 600 has lost its front tunnel bulkhead heat exchanger; the new rear tunnel exchanger is said to be improved to the point where *stockers* now are cooled adequately without the front one in place. Earlier turbo V-Max 600's received, at best, marginal cooling from the stock cooling systems when ridden briskly for long periods of time. 1995 turbo V-Max 600's should have front tunnel heat exchangers added for continuous duty operation. The cooler any engine is kept, the more detonation resistant it will be, and the more horsepower it will make.

Here is our own turbocharged V-Max 600, on pump gas, with 7 psi of boost pressure and three degrees less timing. The power peak here is at 7750 as the result of some long, pipe heating endurance runs we were making while testing the ignition timing. Typically, the power peak will be at 7500 RPM.

TURBO 1994 YAMAHA V-MAX 600 7 psi Boost -185 mj
Data for 29.92 inches Hg, 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .741
Vapor Pressure: .27 Barometer: 29.58

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
6000	72.9	83.3	54.8	161.8	13.6	.66	48
6250	77.0	91.6	59.9	170.3	13.1	.66	48
6500	81.0	100.2	70.5	177.8	11.6	.71	47
6750	84.9	109.1	74.0	182.8	11.3	.69	49
7000	84.9	113.2	78.3	186.9	11.0	.70	49
7250	87.6	120.9	78.8	194.7	11.3	.66	48
7500	90.5	129.2	88.4	199.4	10.4	.69	48
7750	89.0	131.3	99.8	204.2	9.4	.77	48
8000	81.0	123.4	108.1	199.7	8.5	.88	48

TURBO V MAX 600

Increasing the boost pressure to 9 psi with the high-low boost switch, resulted in the following data. This again was with pump gas and three degrees less timing. This boost level would be for intermittent use on pump gas. Long runs (1/4 mile+) should be accompanied by AV gas or better.

TURBO 1994 YAMAHA V-MAX 600-9 psi Boost-185 MJ
Data for 29.92 inches Hg, 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .741
Vapor Pressure: .27 Barometer: 29.58

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
6250	86.2	102.6	73.4	202.6	12.7	.72	52
6500	93.6	115.8	77.4	215.4	12.8	.67	52
6750	95.9	123.3	88.2	222.7	11.6	.72	49
7000	96.4	128.5	101.2	226.2	10.3	.79	50
7250	97.8	135.0	110.1	230.7	9.6	.82	51
7500	99.2	141.7	103.9	236.8	10.5	.73	51
7750	95.5	140.9	97.1	242.1	11.4	.69	53
8000	80.1	122.0	98.1	237.3	11.1	.80	50

Flipping the boost toggle switch to high gave us 11 psi boost requiring 110 octane for any conditions of operation.

TURBO V-MAX600-11 psi Boost-185 mj
Data for 29.92 inches Hg, 60 F dry air
Test: 200 RPM/Sec Acceleration
Fuel Specific Gravity: .741
Vapor Pressure: .27 Barometer: 29.59

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
6000	94.0	107.4	66.6	218.4	15.1	.62	58
6250	95.4	113.5	70.9	223.8	14.5	.62	58
6500	102.8	127.2	77.4	237.3	14.1	.61	60
6750	104.8	134.7	80.5	243.8	13.9	.60	59
7000	106.3	141.7	84.6	249.5	13.5	.60	61
7250	106.3	146.7	88.9	254.5	13.1	.61	61
7500	106.0	151.4	95.6	260.0	12.5	.63	62
7750	99.9	147.4	99.6	264.3	12.2	.68	62
8000	85.7	130.5	102.0	260.2	11.7	.78	61

Here is an independant dyno test done by Orland Auto in Orland Park, IL (708-349-8600). Owner Greg Santry is a distributor of turbo systems (all brands) who had this one pumped up to a 110 octane 12.5 psi of boost. As a side note, Greg had purchased one of the original 200 CBHP (advertised power) V-Max 4 turbo systems in 1992, and when he brought his turbo V-Max 4 to Midwest Dyno Service to check his new turbo system out, he was shocked to see 208+ CBHP on pump gas. More horsepower than advertised?

Since then, Greg has built his own SuperFlow dyno, and now stocks First Choice Turbo systems at his facility.

TURBO 1994 YAMAHA V-MAX 600 12.5 psi Boost-180 MJ
Data for 29.92 inches Hg, 60 F dry air
Test: 300 RPM/Sec Acceleration
Fuel Specific Gravity: .740
Vapor Pressure: .28 Barometer: 29.23

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
6100	90.7	105.3	88.3	226.4	11.8	.86	53
6300	95.8	114.9	88.9	230.9	11.9	.80	53
6500	102.9	127.4	88.9	238.4	12.3	.72	53
6700	103.2	131.7	88.5	242.4	12.6	.69	53
6900	106.3	139.7	89.5	249.8	12.8	.66	53
7100	106.4	143.8	94.0	254.3	12.4	.67	53
7300	107.0	148.7	101.9	258.4	11.6	.70	53
7500	108.6	155.1	105.4	263.1	11.5	.70	53
7700	109.3	160.2	107.1	267.6	11.5	.69	53
7900	107.9	162.3	106.8	271.2	11.7	.68	53
8100	95.4	147.1	117.7	270.0	10.5	.82	53

Finally, after the Midwest Dyno Service guys saw the bizzare amount of horsepower produced by Greg Santry's turbocharged V-Max 4, they bought one for themselves and had great fun with it last winter. This year, they picked up a V-Max 600 turbo system for owner Rich Vetter's V-Max 600. With 7.5 psi of boost, on 92 octane pump gas, here is Rich's trail sled.

TURBO 1994 YAMAHA V-MAX 600 7.5 psi Boost-180 MJ
Data for 29.92 inches Hg, 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .723
Vapor Pressure: .41 Barometer: 29.41

RPM	CBT	CBHP	FUEL	BSFC	CAT
6000	75.7	86.5	64.4	.78	75
6250	80.5	95.8	66.4	.73	75
6500	83.9	103.8	71.9	.73	75
6750	87.9	113.0	70.3	.65	75
7000	89.2	118.9	71.2	.63	75
7250	91.1	125.8	75.1	.63	75
7500	92.6	132.2	78.2	.62	76
7750	90.8	134.0	83.0	.65	77
8000	81.7	124.4	85.8	.73	78

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Interpreting the Data

We receive a number of inquiries from our newer subscribers for further clarification of the data generated on the dyno. For their benefit, we've compiled and reprinted definitions and explanations of the terms used in dynanometer tuning.

CBT and CBHP--"Standard Corrected Brake" torque and horsepower. The data here is the torque and horsepower the same engine would make with a 60 degree Carb Air Temperature at sea level and no humidity. The dynanometer "corrects" the actual obseved horsepower to this standard, allowing for a true "apples and apples" comparison of data, despite differing atmospheric conditions.

FUEL---The fuel flowing into the carburetors. The number in this column is the number of pounds of fuel per hour.

AIR---The amount of air, in units of standard cubic feet per minute, flowing through the engine.

A/F---Air to fuel ratio. The number in this column is the pounds of air for each pound of fuel consumed. (10 is rich and 16 is lean).

BSFC---Brake Specific Fuel Consumption. A measure of the engine's fuel efficiency, it is measured in units of pounds of fuel consumed per horsepower, per hour.

CAT---Carburetor air temperature in degrees Fahrenheit. This is typically close to the ambient air temperature, and it is this temperature that you should use when establishing your jetting specs based upon our data. (A number of subscribers have the misconception that they should jet based upon the "29.92 In. Hg. 60 F. dry air" which appears at the heading of each data table. This is the atmospheric conditions the dyno corrects the torque and horsepower to, and not what our jetting is based upon).

After performing thousands of dyno test runs on a variety of engines, we feel qualified to make jetting recommendations based on the BSFC numbers stored in our data base.

It's been fun, informative, *and sometimes expensive* leaning various engines down to determine just how low a BSFC number they can make on the dyno. As we jet down, fuel flow is reduced and horsepower is increased, resulting in a lower BSFC. Eventually, every engine reaches a balance point where fuel flow is at its minimum and horsepower is at its maximum. Past this point, as fuel flow is reduced, horsepower diminishes rapidly and the BSFC begins to climb.

The lowest BSFC recorded on our dyno has been .37 lb/hphr, attained by Paul Gast's wild four-stroke Kawasaki Pro Stock drag racing motorcycle. Fortunately, this engine only has to endure six second dyno tests and eight second quarter mile runs.

Two-stroke snowmobile engines are not yet able to survive such low numbers. Their pistons are subjected to combustion heat every time around, and must be to a certain extent "liquid cooled" by the vaporization of some unburned fuel. This helps to keep them from growing to a size greater than that of the hole they used to rattle around in.

Snowmobile high compression racing engines that we've tested are sometimes capable of achieving and surviving a BSFC as low as .50 or less for short periods of time.

Stock trail engines often register around .80 or more allowing them to live safely on low octane fuel.

The dilemma faced by manufacturers of high performance snowmobiles and equipment is in providing their customers with performance *and* decent mileage on fuel of sometimes questionable quality, while avoiding costly warranty claims that can result from piston seizures. The harsh reality is that many sled owners will not change their main jets, regardless of conditions. Understandably, the factories usually provide main jet specs that will be safe to well below zero F at sea level.

Remember that as the Carb Air Temperature goes down, Relative Air Density goes up, and there is more oxygen in the engine to consume the extra fuel that was previously only "cooling the fire". Observed horsepower goes up, fuel flow is unchanged, and BSFC is reduced.

For our subscribers who pay attention to changing air density and are willing to change their jets as conditions warrant, DYNO*TECH* would offer the following full throttle BSFC guidelines that we use when dyno tuning our customers' engines:

.70 and higher is a safe spec for pump gas.

.60-.69 requires 92+ octane fuel to resist detonation during sustained high speed operation.

.55-.59 allows short runs on 92+ octane, otherwise 100 + octane Av Gas or racing gas is necessary.

.50-.54 is O.K. for dragracing on 100+ octane gas; for longer runs we recommend 110+ octane gas.

.49 and lower is our "TWILIGHT ZONE" that few snowmobile engines have actually attained. Dragracers can survive here with 110+ octane.

IS THERE A THIRD WAY?

The Cellar Dweller

Kevin Cameron

The 20th century has seen the development of two main types of internal combustion engine; spark ignition (SI) and Diesel, or compression ignition (CI).

In the SI engine, a premixed charge is compressed, then ignited, and a flame front spreads via turbulence to consume the chamber contents. In the CI engine, unthrottled air only is compressed, and to such a degree that it becomes hot enough to ignite fuel that is sprayed at it near TDC.

The notorious limiting problem of the SI engine is knock. That of the diesel engine is its weight and limited speed. Both SI and CI engine have problems in meeting emissions standards.

Could there be a third way? A recent announcement by Honda suggests there may be. Honda's press material on its 400 cc EXP-2 two stroke single is coyly worded and the facts are thin, but here is what we know.

Eleven months ago, Honda presented a paper before the French Petroleum Institute, describing a 250 two-stroke single that operated below 40% throttle without spark ignition. It accomplished this by means of what Honda is calling "AR-Combustion". In this case, AR stands for active radical.

Now for some background material. In any gasoline engine, there are preliminary chemical reactions that occur in the mixture as it is heated by compression, and next by the combustion flame front. These so-called "pre-flame reactions" result from high energy molecular collisions that break up some of the least robust fuel molecules, and include some partial oxidation of them by oxygen in the air. Some of the resulting molecular fragments are chemically very active, and are termed 'active radicals'. Their presence in the fuel-air mixture accelerates chemical change there, and if the flame front takes too long in reaching the end gas, or last part of the unburned mixture, such chemical change will allow the end gas to go off by itself, or auto-ignite. Now being full of active radicals, and in a hair-trigger state, the end gas doesn't burn smoothly, but explodes. This generates the familiar, audible shock wave of detonation, or engine knock.

The potential for knock is built into the concept of spark-ignited, flame front combustion, for as the flame front pushes across the chamber, it severely heats the end gas, pushing it into the chemically active state that makes it prone to detonate.

You'd think therefore, that engineers would work hard to suppress the formation of active radicals. They have. That's the whole reason for high octane fuels, and for fast-burn technology. So it's a paradox that there could be a system of combustion that is based upon deliberate use of the very radicals that lead to detonation in the first place.

How many of you have seen an engine run away, and continue to rev out even after the plug wires were pulled? Most experienced two-stroke people have seen this at least once, and it's a puzzling phenomenon. Most of us dismiss it as "dieseling" or do a little pseudo-learned arm waving about slow combustion mumble, mumble, lean mixture, mumble, lingering flame, etc.. Mr. Toyoda, of the Toyota Motor Co., asked his engineers to find the reason, and the same question has been tackled elsewhere.

We can dismiss the Dieseling claim at once by noting that compression of air to spark-ignition compression ratios does not make it hot enough to burn fuel by itself--as does happen in diesels, with their CRs of from 17:1 to 23:1. Getting a little closer to the mark is what makes pulse-jets--like the powerplant of the WW II German V1 "buzzbomb"--continue to run entirely without ignition. What the Toyota engineers, and others before them and after them, discovered, is that under the right circumstances, active radicals from one combustion event can persist to the next combustion event. When enough of them have mixed with the fresh charge, they reduce its

IS THERE A THIRD WAY

The Cellar Dweller Kevin Cameron

ignition energy requirement so much that even the modest compression in the SI engine (or in a buzz-bomb duct) is enough to ignite the whole charge. Result; the engine runs, even when the ignition is shut off.

The kicker is the phrase, "under the right circumstances". A Japanese researcher named Onishi, and others, found that this kind of active-radical combustion could occur only at low speeds and throttle. If too much fresh charge were admitted, its low temperature and large mass would quench the action of the active radicals, and the engine would stop.

This kind of engineering isn't very fashionable. When Onishi and others sent their papers in to the SAE, they declined to publish them because they were too weird, too far out. Only when Mercury Marine's Ben Schaefer sponsored them, were they published. This attitude is general. Work of this kind is considered odd and irrelevant.

Honda has gone further. Workers at Honda R&D mapped out precisely the envelope of possible active-radical operation, and discovered that if they controlled the temperature at the start of compression, (by putting a valve in the exhaust that could adjust the proportion of exhaust to fresh charge) they could make active-radical ignition operate smoothly, controllably, and entirely without detonation up to about 40% throttle. At higher throttle, the engine had to switch to spark ignition or it would misfire and then stop.

Why didn't charge seeded with active radicals just push the engine straight into destructive detonation? The reason has to do with the two kinds of combustion; spark ignition vs. radical-initiated. When the charge is ignited by spark, a flame front is generated which sweeps across the combustion chamber, at the fairly high speed of 50-250 feet per second. This flame front acts like a piston, severely compressing and heating the last parts of the charge. It is this abuse of the so-called end gas that leads to detonation; the end gas is subjected to increasing heat throughout the entire combustion process, which creates a big population of active radicals within it that go bang when they finally ignite.

But, in radical-initiated combustion, almost uniform conditions exist in all parts of the chamber at any given moment, and all elements of the charge advance together through the chemical reaction steps that constitute combustion. There is no end gas being compressed and heated, so there is no detonation.

OK, so there's a trick third way to burn fuel. Where's the beef, aside from its resistance to detonation?

Right now, all makers of engines--whether two-stroke, four-stroke, or Diesel--are spending big money to meet exhaust emission standards, and they aren't sleeping very well either because they know that wise planners like the California Air Resources Board, the Swiss, and others are busily typing up new regulations that will be even harder, if not impossible, to meet. For a while, it looked as though Diesels were the answer, but then the particulates in their exhaust were discovered to be wonderfully carcinogenic (PAH-phobia), so now they are trying to strain out the little black flecks with improbable filters. Four-stroke lean-burn is fashionable right now, but it's not at all easy to make these engines run smoothly. Two-stroke direct-injection engines created a flurry in about 1989-91, but now the big hang-up is worry that they make too much nitrogen oxide, the result of excessive combustion temperature. Since no one is in heaven, there is a lot of scheming as to how to get there.

Well, the neato thing about active-radical combustion is that it can make lean-burn work. The problem with conventional lean-burn is that it takes so much ignition energy to set off the lean charge, you could almost run the engine just on its ignition heat. But, if you seed that lean charge with active radicals, its ignition energy requirement starts to come down, down, down. I think the clever lads and lasses at Honda are looking hard at this interesting fact.

Honda R&D plans to enter an AR-combustion powered 400cc two-stroke in next year's Grenada-Dakar race. Is this because they plan to make lots of weird-combustion dirt bikes, and sell them to us? I suppose they might, but a more likely reason is that by showing such a machine, they will be telling skeptical engineers everywhere that Honda can do what they can't do. Fenced about with Honda's traditional hundreds of patents, AR-combustion might become a valuable asset.

IS THERE A THIRD WAY?

The Cellar Dweller **Kevin Cameron**

Because spark-ignited combustion generates a flame front, each charge element is actually in the flame front for only a tiny instant as it sweeps through. To produce complete combustion, a lot of chemistry has to occur in that instant. In radical-initiated combustion, there is no flame front because all parts of the charge advance together towards completion. Density-sensitive photography of AR-combustion shows a multitude of ignition sites throughout the chamber. This increases the time of reaction for all mixture elements, resulting in more complete combustion.

Yet another difference concerns consistency. In spark-ignited combustion, there are considerable variations in peak pressure from cycle to cycle. These are caused by small differences in how quickly the initial flame kernel grows into an actual moving flame front. Engineers have always looked longingly at pressure-volume plots of successive cycles, put a forefinger on the best cycle with the highest pressure, and said "Wouldn't it be nice if every cycle could be as nice as this one here!". Some things reduce SI cyclic variation, but it never goes away entirely. The longing looks continue to this day.

Radical-initiated combustion makes cyclic variation go away. Because its operation depends on average properties, and not upon the accident of which way and how hard the wind of the in-cylinder turbulence was blowing when the spark went off, the time and amplitude of peak pressure are remarkably consistent. This means there is a potential power gain in AR combustion as well.

Honda isn't the only interested party. Sonex Corp. in Annapolis, Md. stores products of partial combustion in pistons or other cavities, so that they outgas during the piston stroke, seeding the fresh charge with active radicals. The Toyota-Soken combustion process likewise makes use of radical ignition. Smokey Yunick created quite a stir a few years ago with his hot vapor cycle engine, which was a two-stroke whose intake charge was intentionally heated to produce a population of active radicals--and it didn't knock. The Russians Semenov and Gussak developed a jet igniter system (LAG process) that generated active radicals and simultaneously shot them across the combustion chamber. There is quite a little underground of subversive engineering going on that has, up till now, been hardly audible. We await developments.

Suggestions For Further Reading

On the chemistry of pre-flame reactions, there's nothing better than the very clear work of Sturgis, "Some Concepts of Knock and Anti-Knock Action", SAE Transactions, Vol. 63, 1955

The papers of Onishi and Noguchi describe earlier Japanese work on radical-initiated combustion; Noguchi et al., "A Study on Gasoline Engine Combustion by Observation of Intermediate Reactive Products During Combustion", SAE 790840, 1979

Onishi et al., "Active Thermo-Atmospheric Combustion-A New Combustion Process for Internal Combustion Engines", SAE 790501, 1979

About Honda's developments in this area; Ishibashi and Tsushima, "A Trial for Stabilizing Combustion in Two-Stroke Engines at Part Throttle Operation", available from the SAE in a volume entitled "A New Generation of Two-Stroke Engines for the Future?", Seminar of IFP, Nov. 29-30, 1993

SAE Materials are available by calling 412-776-4970, fax 412-776-0790

An excellent overall review is available from Sonex Corp., The Evolution of the Sonex Combustion System", July, 1994. Sonex is located in Annapolis, Md., telephone 410-266-5556

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