Volume 6 Number 1 1994

DYNOTECH

JOURNAL OF SNOWMOBILE PERFORMANCE & TWO STROKE TECHNOLOGY

1995 Yamaha V-Max 800 stock evaluation

Here's the new V-Max 800, production version that we tested in late spring of this year. Sorry about the delay.

Bigger bore, lower exhaust ports (about the same as the '92 750), extra tiny exhaust ports above each front transfer, and a single large Phazer-like intake port instead of the 750's three-bridged intake. Why eliminate the bridged intake ports? On some mod engines, they were a source of nickasil woes. Though the new intake port provides less support for the piston (on the reverse rotating V-Max 4 cylinder engines, the intake side of the piston carries the thrust load), it is still more than adequate.

There is a major change in the jackshaft drive on the engine; each two-cylinder crank half has its own narrow rubber dampened gear that drives onto a double-wide driven gear on the output shaft. The effect of this is to minimize the difficulties that some early V-Max 4 owners had with crankshafts due to torsional vibrations, especially at high engine speeds.

The V-Max 800 also has the rev limiter set at 10,000 RPM to accomodate high RPM engine modifications. The ignition timing curve appears to be correct for such operation as well.

My favorite pet peeve is oil injection into the fuel lines before the fuel pumps. The V-Max 800 still has the same setup. My second favorite pet peeve is the underhood pressurization of the big Yamahas. Our V-Max 800 had the stock winter 141.3 main jets left in place for our 80 degree dyno test session. As the data shows, the BSFC was a pump gas safe .65.

One other interesting phenomenon with the new engine is that apparently, the 800 twin pipes are substantially better performing than the stock 750 twin pipes. The main difference is a larger diameter pipe between the Y and the divergent cone. The stampings appear identical. We installed our set of Bender 750 twins on the 800, and made virtually the same power as stock. Then, we installed our Bender quad pipes and got only a 10 CBHP gain to 160+ CBHP! Last year's 750 stocker had its power increased by about 20 to 160+ CBHP with the same quad pipes.

More research will be done to see if the 750 engine makes 150 CBHP with the 800 stock pipes, or if the 800 engine will make 140+ CBHP with the 750 stock pipes.

For sure, the larger bore and/ or triple exhaust port configuration of the new engine is a benefit in the full mod versions that we have seen. Improved Stock 800 engines are making 200+ CBHP. Whether or not it is helping the low RPM stock

1995 yamaha VMax800 continued

engine that much remains to be seen. Our bet is that the pipes are greatly responsible for the low RPM power increase.

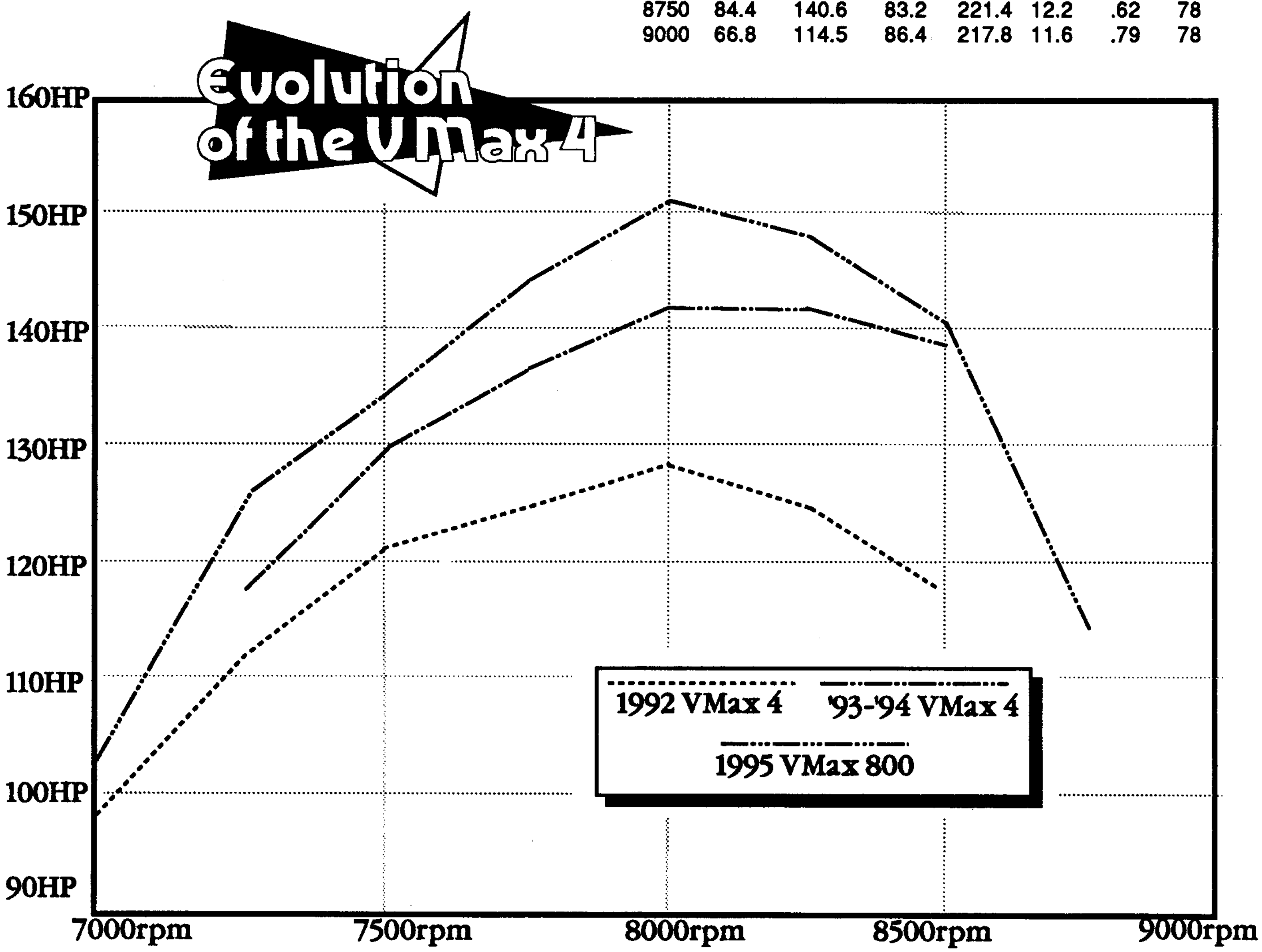
Regardless of the cause, the new V-Max 800 engine represents an improvement over the earlier 750 engines. Combined with the new Cat-like rear clutches which are receiving rave reviews from early summer grassracers, the new V-Max should be more of a contender this year in the Battle of Old Forge 800 class.

1995 V MAX 800 STOCK

141.3 mj

Data for 29.92 in. Hg, 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .750
Vapor Pressure: .72
Barometer: 29.85

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
7000	84.8	113.0	70.6	175.6	11.4	.65	76
7250	92.8	126.1	77.9	186.2	11.0	.64	76
7500	94.1	134.4	87.2	191.4	10.0	.68	76
7750	97.8	144.3	83.0	200.0	11.0	.60	78
8000	98.1	143.4	97.0	206.8	9.8	.68	78
8250	96.4	151.4	95.2	212.6	10.4	.65	79
8500	91.2	147.6	92.0	218.2	10.8	.65	78
8750	84.4	140.6	83.2	221.4	12.2	.62	78
9000	66.8	114.5	86.4	217.8	11.6	.79	78



PIPE SHOOTOUT #31

ARCTIC CAT THUNDERCAT

We've seen in the past that Arctco does not typically leave a lot of horsepower "on the table" when they design their factory production pipes. The aftermarket pipe builders have to work hard to design replacement exhaust systems that exceed stock horsepower without spinning the engines at excessively high RPMs.

In the past, we've tried various mutations of the stock factory triple Thundercat pipes (shortened header pipes and/or center sections) on the stock engine with unsatisfactory results; we only succeeded in raising the power band, but lost so much torque in the process that the resulting horsepower was the same or less than stock. Shortening the stock pipes is desirable only on modified engines.

Noise is an issue that is becoming increasingly important. In the old days (six years ago and pre-DynoTech), we used to equate loud pipes with high output engine performance. Snowmobiles couldn't be fast unless their exhaust sound levels exceeded the threshold of pain. The louder they were, the faster they must be. Today, we partially-educated performance people know that two-stroke engines are easily quieted without any sacrifice in power. In any situation, an open external stinger can be replaced with an efficient muffler with no loss of horsepower.

Unfortunately, not all performance snowmobilers are aware of this fact. It is possible that the excessive noise levels of some aftermarket exhaust systems are intended to sell product to the less knowledgeable consumer. The educated DynoTech readers use horsepower output as the primary factor in making their decisions. Unfortunately, we still remain a vocal minority, and noise levels are sure to remain high as long as some people perceive the loudest as being the best.

Here are the dyno test results of a typical stock 900 Thundercat which was dyno tested with all of the currently available aftermarket triple pipes. As I understand it, the noise level increases exponentially, doubling at every three dB increase! I would like for some informed subscriber to explain this for us.

Speaking of noise, we tested D&D Cycle's Three-Pack exhaust silencer system that they sell for use with the stock or cut stock pipes. They just duplicated the stock cannister muffler's power output, but registered 100+ dB. The idea behind these is only to save weight over the rather heavy stock muffler.

For our 31st pipe shootout, we utilized our airflow meter by connecting the large and small airbox inlets with an arrangement of PVC pipe and fittings. We dyno tested the T-Cat engine both with and without the airflow meter ducting and there was no affect on power output. For some reason, though, our airflow readings were low, as evidenced by the low A/F ratio readings (engines typically misfire at A/F ratios richer than 10-1) accompanied by quite normal BSFC. Though the airflow readings appeared low, they were consistent enough to compare the restrictions of the different pipes' mufflers.

We used unleaded 93 octane gasoline for all of the testing. 370 main jets gave us reasonably safe fuel flow for the mid-60 degree F air (CAT) of the day of the test. Two to three runs were made on each setup to ensure repeatable results (within less than .5%).

1994 THUNDERCAT STOCK 88 dB
Data for 29.92 in. Hg, 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .741
Vapor Pressure: .12 Barometer: 29.58

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
6000	81.3	92.9	69.2	183.3	11.8	.83	64
6250	83.7	99.6	79.6	187.3	10.8	.83	64
6500	88.4	109.4	82.0	196.6	10.7	.77	65
6750	89.1	114.5	87.7	199.7	10.4	.79	64
7000	90.7	120.9	95.4	202.3	9.8	.82	64
7250	93.3	128.8	99.7	204.8	9.6	.80	64
7500	86.7	138.1	101.6	209.7	9.6	.77	64
7750	101.8	150.2	104.2	219.1	9.8	.72	64
8000	105.9	161.3	104.7	227.9	10.2	.67	65
8250	105.9	166.4	117.2	235.5	10.4	.73	64
8500	102.4	165.7	104.2	238.4	10.2	.65	64
8750	91.4	152.3	103.6	238.2	9.9	.69	65

The PSI triple pipes are stamped, with individual silencers exiting out the stock outlet. They added four ft/lb of torque and four CBHP and were the second loudest, registering 14 dB more than stock.

1994 THUNDERCAT
370 mj PSI PIPES 100 dB
Data for 29.92 in. Hg, 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .741
Vapor Pressure: .12
Barometer: 29.56

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
6000	86.6	98.9	82.8	193.5	10.7	.86	64
6250	90.9	108.2	85.5	204.2	11.0	.81	65
6500	95.2	117.8	90.3	214.6	10.9	.78	65
6750	98.2	126.2	95.4	217.4	10.5	.77	65
7000	99.4	132.5	99.4	218.2	10.1	.77	66
7250	101.1	139.6	103.7	223.9	9.9	.76	65
7500	105.4	150.5	114.8	231.2	9.2	.78	65
7750	109.3	161.3	118.8	240.0	9.3	.75	63
8000	110.7	168.6	111.5	248.8	10.2	.68	64
8250	107.8	169.3	116.3	251.8	9.9	.70	64
8500	101.3	163.9	113.4	249.6	10.1	.71	64
8750	85.1	141.8	116.2	244.1	9.6	.84	64

Aaen uses hand welded cone construction for their Thundercat pipes. Noticeably lighter than the rest, they also were the quietest at only four dB over stock (still more than twice as loud). We believe that the Aaen pipes utilized internal stingers for part of their muffling; they were noticeably more restrictive than the other pipes. This seemed acceptable for the stock engine, but would prove to be too tight for the ported engine we would test later. On our stock engine, the pipes peaked at 8750 RPM, with four less ft/lb of torque but, more importantly, a five CBHP increase.

1994 THUNDERCAT
370 mj AAEN PIPES 90 dB
Data for 29.92 in. Hg, 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .742
Vapor Pressure: .12
Barometer: 29.53

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
6250	79.1	94.1	72.7	175.7	11.1	.79	68
6500	84.8	105.0	81.5	192.5	10.8	.80	68
6750	86.8	111.6	88.1	197.1	10.3	.81	67
7000	87.8	117.0	93.2	199.4	9.8	.82	67
7250	88.9	122.7	97.8	200.3	9.4	.82	67
7500	92.2	131.7	99.6	203.9	9.4	.78	68
7750	95.9	141.5	101.2	209.6	9.5	.74	68
8000	97.8	149.0	102.0	214.0	9.6	.70	68
8250	100.0	157.1	99.5	220.2	10.2	.65	68
8500	102.9	166.5	103.5	229.6	10.2	.64	67
8750	102.5	170.8	105.2	235.4	10.3	.63	69
9000	93.8	160.7	105.8	235.5	10.2	.68	69

Reichard Performance Center uses blown pipes for the Thundercat, exiting out the stock bellypan hole.

The RPC pipes made marginally the most HP on the stock engine with a three ft/lb torque increase and six more CBHP. They also were the loudest with a 14 dB increase over stock.

1994 THUNDERCAT
370 mj REICHARD PIPES 102dB
Data for 29.92 in. Hg, 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .742
Vapor Pressure: .12
Barometer: 29.52

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
6250	89.2	106.2	83.7	199.9	11.0	.81	66
6500	92.0	113.9	89.6	207.6	10.6	.81	66
6750	95.9	123.3	94.3	210.5	10.3	.79	68
7000	98.4	131.2	100.7	212.8	9.7	.79	69
7250	101.0	139.4	102.5	215.8	9.7	.76	69
7500	103.3	147.5	106.4	220.2	9.5	.74	69
7750	105.5	155.7	113.1	226.6	9.2	.75	69
8000	107.6	163.9	112.4	233.0	9.5	.71	69
8250	109.2	171.5	102.5	240.7	10.8	.61	69
8500	105.8	171.2	106.7	243.2	10.5	.64	69
8750	99.8	166.3	108.6	243.8	10.3	.67	68
9000	86.2	147.7	107.9	238.9	10.2	.75	68

Since the introduction of the case reed inducted Thundercat in model year 1992, reed petal material changes have played a significant role in all of the dyno testing that has been done on stock and modified engines here. To date, the stock Thundercat reeds have been as good or better than any aftermarket reeds we have tried. We've seen many people spend many hours dyno testing many types of reeds with disappointing results. So, we were understandably leery of the rather pricey billet V-Force reed cages and reeds that D&D Cycles was considering selling to their customers.

The V-Force reed cages are manufactured by Moto Tassinari, and consist of a double set of fiber reeds in each W-shaped billet aluminum cage. Machining of the cages from solid blocks of aluminum obviously contributes to the high cost of the V-Force reeds; Moto Tassinari is currently exploring having castings made which will reduce the cost in the near future. We installed the V-Force reed cages on the stock engine after the RPC pipes were installed. We were happy to see a 4-5 HP increase on top end with no loss in the bottom end power.

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1994 THUNDERCAT
370 mJ REICHARD PIPES
V-FORCE REEDS
Data for 29.92 in. Hg. 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .742
Vapor Pressure: .12
Barometer: 29.48

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
6500	92.3	114.2	88.1	202.7	10.6	.80	72
6750	95.4	122.6	96.2	209.2	10.0	.81	71
7000	98.0	130.6	105.2	215.0	9.4	.83	71
7250	99.7	137.6	113.9	217.7	8.8	.86	71
7500	102.4	146.2	109.8	220.2	9.2	.78	73
7750	105.2	155.2	112.2	226.5	9.3	.75	72
8000	108.4	165.1	110.8	235.6	9.8	.69	72
8250	110.0	172.8	114.6	241.6	9.7	.69	73
8500	108.1	175.0	111.5	244.7	10.1	.66	73
8750	102.3	170.4	114.9	244.5	9.8	.70	73

D&D Cycles in nearby central NY spends lots of time at the C&H Dyno. As is obvious judging by their successes on our dyno and at the dragraces the past few years, they are capable of making Arctic Cats perform extremely well. We have used their stuff in many of our hop-up projects in the past, which has been convenient for us and helpful to many of our subscribers.

There are, however, many other Cat modifiers around the country also very capable of doing excellent engine work. I have extended the opportunity to many others to avail themselves of our public testing facility to share their work with our subscribers. RPC's Jeff Simon tells me that his own T-Cat port dimensions are "optimized" for his pipes. Perhaps some day we will do a cylinder porting shoot-out or something like that.

The fact that we have used D&D Cycles' cat stuff is more a matter of logistics than preference for their undisputable good work. Dale and Dan Roes are both workaholics dedicated to the Cat Cause, and we at DynoTech are grateful that they live nearby. Dale and Dan are similarly grateful that we are nearby to them.

The point here is that there is a long list of qualified Cat modifiers around the country–Black Magic, Hooper Racing, Cutler, Norton Performance, CycleDyne, M5, Decker, Anoka Ramsey, RPC, and probably many others who will undoubtedly chew my butt for forgetting to mention them.

Part 2
Performance Improvements

After performing our stock 900 pipe shootout, we installed a set of trail ported big-bore 1,000 cc cylinders that had been done by Dale Roes of D&D Cycle. These have Nickasil coated cylinder bores, and are mildly ported for moderate RPM pump gas "trail" performance. This session was a somewhat helter-skelter procession from pipes to carbs to reeds to compression to carbs to reeds to pipes, etc. **THIS WAS NOT A PIPE SHOOTOUT**, but an exercise in obtaining, in comparatively minute increments, amazing normally aspirated pump gas horsepower. The RPC pipes, which were relatively neglected in this excercise, surely are capable of 200+ pump gas HP when tweaked to optimum like we did with the PSI and stock pipes.

Also, Brec Norton of Norton Performance in Essex Junction, VT, sent us a set of his cut stock pipes to test on this engine. However, his shipping company goofed and they wound up in North Carolina instead of Batavia, NY. Perhaps we can try them next time.

Following is the key data from 52 one-step-at-a-time dyno test runs. As before, we ran all of these 15 second full throttle acceleration tests on 93 octane pump gas, with two or more runs on each combo to ensure <.5% repeatability.

We started off with the 1000 trailport cylinders, fairly low 130psi cranking compression, with stock 38mm carbs, V-Force reed cages, and the RPC pipes.

1994 THUNDERCAT 1000 TRAIL PORT
38 mm CARBS-370 mJ-REICHARD PIPES
V-FORCE REEDS-130 PSI CRANKING COMP.
Data for 29.92 in. Hg. 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .742
Vapor Pressure: .12 Barometer: 29.52

RPM	CBT	CBHP	FUEL	BSFC	CAT
6500	96.4	119.3	90.4	.77	57
6750	101.0	129.8	96.3	.76	58
7000	103.1	137.4	105.6	.78	57
7250	107.1	147.8	120.8	.83	58
7500	109.6	156.5	122.3	.80	58
7750	112.6	166.2	111.8	.69	58
8000	115.2	175.5	108.6	.63	57
8250	116.2	183.3	113.3	.63	58
8500	116.9	189.2	110.4	.59	58
8750	113.9	189.8	113.1	.61	57
9000	107.6	184.4	111.5	.62	57

We removed the RPC pipes and installed the stock pipes and cannister, and lost three HP.

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1994 THUNDERCAT-1000 TRAIL PORT
38 mm CARBS-370 mj STOCK PIPES
V-FORCE REEDS-130 PSI CRANKING COMP.
Data for 29.92 in. Hg, 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .742
Vapor Pressure: .12
Barometer: 29.52

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
6000	87.0	99.4	88.2	201.4	10.5	.90	54
6250	90.7	107.9	90.1	205.6	10.5	.85	54
6500	96.0	118.8	93.1	217.9	10.7	.79	53
6750	97.4	125.2	100.1	223.2	10.2	.81	53
7000	99.1	132.1	110.9	225.4	9.3	.85	53
7250	102.0	140.8	124.9	229.0	8.4	.90	54
7500	107.2	153.1	122.7	235.2	8.8	.81	54
7750	111.7	164.8	114.0	243.2	9.8	.70	54
8000	115.6	176.1	107.2	250.9	10.7	.62	54
8250	117.0	183.8	109.8	257.6	10.8	.61	54
8500	115.8	187.4	106.9	261.2	11.2	.58	54
8750	109.9	183.1	119.7	262.7	10.1	.66	53
9000	100.1	171.5	114.3	258.4	10.4	.68	55

Continuing our backwards slide, we installed stock reed cages and lost another four HP.

1994 THUNDERCAT-1000 TRAIL PORT
38 mm CARBS-370 mj STOCK PIPES
STOCK REEDS-130 PSI CRANKING COMP.
Data for 29.92 in. Hg, 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .742
Vapor Pressure: .12
Barometer: 29.55

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
6000	85.6	97.8	85.7	198.5	10.6	.89	54
6250	91.9	109.4	90.2	207.3	10.6	.84	55
6500	94.4	116.8	97.4	215.1	10.1	.84	54
6750	95.8	123.1	101.4	216.7	9.8	.83	55
7000	99.9	133.1	107.3	221.1	9.5	.82	55
7250	102.4	141.4	110.9	225.8	9.4	.79	52
7500	106.6	152.2	114.8	231.4	9.3	.76	54
7750	110.8	163.5	112.2	236.8	9.7	.70	55
8000	114.6	174.6	108.8	245.7	10.4	.63	53
8250	115.1	180.8	120.8	251.7	9.6	.68	54
8500	113.2	183.2	123.0	254.0	9.5	.68	55
8750	107.7	179.4	121.7	254.7	9.6	.69	54
9000	93.5	160.2	118.1	249.3	9.7	.75	54

Next, weremoved the airbox, installed larger carb boots and 44mm carbs. 480mj kept the BSFC pump gas safe, and we picked up 10 HP, some of which was due to leaner jetting While we don't have the data shown here, the large carbs made the same torque and HP with both the stock and V-Force reed cages.

1994 THUNDERCAT-1000 TRAIL PORT
44 mm CARBS-480 mj-STOCK PIPES
V-FORCE REEDS-130 PSI CRANKING COMP.
Data for 29.92 in. Hg, 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .742
Vapor Pressure: .12
Barometer: 29.56

RPM	CBT	CBHP	FUEL	BSFC	CAT
6250	93.8	111.6	84.6	.76	53
6500	98.1	121.4	85.1	.71	53
6750	101.6	130.6	85.6	.66	53
7000	104.1	138.7	89.3	.65	54
7250	107.5	148.4	98.2	.67	53
7500	111.7	159.5	107.0	.68	55
7750	113.8	167.9	109.6	.66	54
8000	117.6	179.1	114.6	.65	54
8250	120.0	188.5	121.4	.65	55
8500	119.6	193.8	120.3	.63	54
8750	115.6	192.6	118.8	.62	53
9000	107.7	184.6	117.0	.64	55

We removed the stock pipes and installed our Aaen triples. We made six more HP with these pipes, but apparently the additional restriction of these pipes caused the pistons to overheat and scuff slightly. We were unable to back this run up (the second run produced only 198 CBHP) because of the resulting loss of ring seal.

1994 THUNDERCAT-1000 TRAIL PORT
44 mm CARBS-480 mj-AAEN PIPES
V-FORCE REEDS--130 PSI CRANKING COMP.
Data for 29.92 In. Hg, 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .742
Vapor Pressure: .12 Barometer: 29.57

RPM	CBT	CBHP	FUEL	BSFC	CAT
6500	92.3	114.2	84.5	.75	54
6750	96.5	124.0	86.7	.71	54
7000	101.9	135.8	89.8	.67	54
7250	104.7	143.6	95.3	.67	54
7500	106.2	151.7	102.9	.69	54
7750	107.0	157.9	107.2	.69	53
8000	110.5	168.3	111.1	.67	54
8250	113.6	178.4	115.1	.65	55
8500	118.2	191.3	117.9	.62	55
8750	119.5	199.1	118.0	.60	54
9000	117.9	202.0	114.6	.57	54

Next, we freshened the engine to restore the lost power. We also installed slightly higher compression heads (140 psi). Back to the stock pipes again. This was day two of our test session--the CAT had warmed up 20 degrees, so we should have dropped a couple of jet sizes.

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The richer jetting offset the slightly higher compression, and virtually identical torque and HP numbers were the result.

1994 THUNDERCAT-1000 TRAIL PORT
44 mm CARBS-480 mj
STOCK PIPE-3-PACK SILENCERS
V-FORCE REEDS-140 PSI CRANKING COMP.
Data for 29.92 in. Hg, 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .742
Vapor Pressure: .60 Barometer: 29.69

RPM	CBT	CBHP	FUEL	BSFC	CAT
6250	98.0	116.6	86.8	.78	78
6500	102.4	126.7	89.1	.74	78
6750	106.9	137.4	91.0	.70	78
7000	109.4	145.8	94.1	.68	77
7250	110.2	152.1	99.5	.69	78
7500	113.1	161.5	104.7	.68	78
7750	117.4	173.2	109.5	.66	78
8000	120.0	182.8	113.8	.65	78
8250	122.2	192.0	117.9	.65	78
8500	122.0	197.4	120.9	.64	78
8750	117.9	196.4	120.7	.65	79
9000	107.4	184.0	117.9	.67	77

We installed a set of stock pipes which had been shortened 1" in the header pipes and 1" in the center sections. The Three-Pack silencers were used here.We lost six ft/lb of torque, but gained one CBHP because the power peak had been raised 500 RPM to 9000. Trail riders would probably be better off with the stock length pipes and the lower operating speed.

1994 THUNDERCAT-1000 TRAIL PORT
44 mm CARBS-480 mj
SHORTENED STOCK PIPE-3-PACK SILENCERS
V-FORCE REEDS-140 PSI CRANKING COMP.
Data for 29.92 in. Hg, 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .742
Vapor Pressure: .60 Barometer: 29.71

RPM	CBT	CBHP	FUEL	BSFC	CAT
6250	86.2	102.6	84.0	.86	81
6500	88.9	110.0	85.4	.82	82
6750	97.6	125.4	86.6	.73	81
7000	101.4	135.1	91.5	.71	83
7250	104.7	144.5	99.0	.72	82
7500	106.8	152.5	103.5	.72	83
7750	107.4	158.5	108.4	.72	83
8000	109.0	166.0	110.7	.71	83
8250	111.4	175.0	113.6	.69	84
8500	114.2	184.8	115.7	.66	82
8750	116.6	194.3	117.4	.64	82
9000	115.8	198.4	114.3	.61	83
9250	111.1	195.7	112.7	.61	83

Since we were nipping at 200 reliable horsepower, but not quite there, we installed our PSI triple pipes and picked up six horsepower. We were now making champagne horsepower on pump gas.

1994 THUNDERCAT-1000 TRAIL PORT
44 mm CARBS-480 mj-PSI PIPES
V-FORCE REEDS-140 PSI CRANKING COMP.
Data for 29.92 in. Hg, 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .742
Vapor Pressure: .60
Barometer: 29.68

RPM	CBT	CBHP	FUEL	BSFC	CAT
6500	104.5	129.3	88.5	.72	77
6750	108.5	139.4	88.8	.67	78
7000	111.7	148.9	95.1	.67	76
7250	114.3	157.8	101.8	.68	77
7500	118.0	168.5	109.1	.68	77
7750	124.7	184.0	115.5	.66	78
8000	128.0	195.0	119.6	.64	77
8250	128.1	201.2	126.5	.66	78
8500	126.0	203.9	124.8	.64	79
8750	120.6	200.9	122.4	.64	79

We removed the 44 mm carbs and large flanges, and installed stock flanges with the V-Force reeds. We used a set of stock carbs which had beenbored out to 39.2mm. 400 main jets gave us a similar mid sixties BSFC. This proved to be slighty more powerful than the large 44mm carbs in this application, but they required the V-Force reeds to accomplish this.

1994 THUNDERCAT-1000 TRAIL PORT
39.2 mm CARBS-400 mj
PSI PIPES
V-FORCE REEDS-140 PSI CRANKING COMP.
Data for 29.92 in. Hg, 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .742
Vapor Pressure: .60 Barometer: 29.65

RPM	CBT	CBHP	FUEL	BSFC	CAT
6250	100.7	119.8	122.3	1.07	77
6500	106.1	131.3	114.9	.92	77
6750	111.7	143.6	113.1	.83	77
7000	113.4	151.1	113.0	.78	75
7250	115.3	159.2	116.3	.77	77
7500	121.1	172.9	116.7	.71	77
7750	124.8	184.2	120.1	.69	76
8000	130.2	198.3	122.2	.65	76
8250	130.2	204.5	124.7	.64	77
8500	126.6	204.9	124.4	.64	77
8750	120.9	201.4	124.3	.65	77
9000	109.8	188.2	123.1	.69	76

→

One more time, back to the stock pipes with three-pack silencers with the 39.2mm carbs and V-Force reed cages. This was pretty much a duplicate of the stock-pipe runs with 44mm carbs and either the stock or V-Force cages.

1994 THUNDERCAT-1000 TRAIL PORT
39.2 mm CARBS-400 mj
STOCK PIPES-3-PACK SILENCERS
V-FORCE REEDS-140 PSI CRANKING COMP.
Data for 29.92 in. Hg, 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .742
Vapor Pressure: .60 Barometer: 29.65

RPM	CBT	CBHP	FUEL	BSFC	CAT
6250	96.9	115.3	83.0	.76	79
6500	99.4	123.0	91.3	.78	79
6750	106.5	136.9	94.7	.73	79
7000	109.2	145.5	100.7	.73	80
7250	108.7	150.1	106.9	.75	81
7500	110.7	158.1	108.3	.72	80
7750	117.5	173.4	110.1	.67	80
8000	120.3	183.2	110.2	.64	81
8250	122.8	192.9	120.0	.66	79
8500	122.2	197.8	120.0	.64	80
8750	116.3	193.8	115.4	.63	80
9000	105.4	180.6	105.2	.62	80

Finally, we reinstalled the stock quiet factory canister muffler, and it was virtually identical to the louder three-pack.

1994 THUNDERCAT-1000 TRAIL PORT
39.2 mm CARBS-400 mj
STOCK PIPES-FACTORY MUFFLER
V-FORCE REEDS-140 PSI CRANKING COMP.

Data for 29.92 in. Hg, 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .742
Vapor Pressure: .60
Barometer: 29.65

RPM	CBT	CBHP	FUEL	BSFC	CAT
6250	97.3	115.8	82.1	.75	81
6500	102.9	127.4	86.7	.72	81
6750	105.5	135.6	88.8	.69	81
7000	109.0	145.3	96.4	.70	81
7250	110.3	152.3	106.6	.74	81
7500	113.4	161.9	108.1	.71	81
7750	117.5	173.4	110.8	.67	79
8000	123.2	187.7	115.4	.65	79
8250	124.1	194.9	114.2	.62	81
8500	121.9	197.3	113.5	.61	81
8750	116.2	193.6	113.1	.62	82
9000	104.7	179.4	111.0	.65	80

CONCLUSION

This 1000cc trail engine is a combination that, it its basic form has proven itself over the past winter. One local subscriber, Sonny Hawkins, put over 2000 miles on his stock carbed and stock piped D&D 1000 trailport T-Cat.

WE LEARNED that the V-Force reeds, though expensive, are a fine compliment to the smaller carbs. In the field, D&D has found that the smaller 39.2mm carbs with V-Force cages ET more quickley than do the 44mm carbs.

As we suspected, the stock pipes are excellent, but can be exceeded a bit by the PSI, RPC, and Aaen (on the stock engine only) pipes. The Aaen pipes could probably be made to work with the larger modified engine by removing the internal stingers to relieve some of the back-pressure. They would, of course, become much louder.

Anyone attempting this modification would be well advised to use an instrumented dyno to do it correctly.

Those Three-Pack silencers that D&D sells seem to make the same power as the stock can- except for one particular combination of 44mm carbs and stock pipes, where we saw a three Horsepower increase.

And of course, because the new 800 engine shares an identical crankcase and crankshaft with the 900, all of these cylinder/ carb/ reed/ pipe mods will apply to it as well.

How Much?

We began this 1000cc excercise with basically 185 CBHP. A few HP here, a few HP there, and we wound up with an extra 20 CBHP. The cost of this whole package is as follows:

D&D 1000 trail port cylinders, cut heads, exchange price, 20 CBHP	$1400.00
V-Force reeds, billet style, 5 CBHP	$ 398.00
Bore stock carbs to 39.2mm, 5 CBHP	$ 35.00 ea.
Aftermarket pipes, 10 CBHP	$ 525.00

RACE ENGINES

CRANK SHOP MOD STORM & MACH Z

Here are a pair of Crank Shop (802-878-3615) modified engines that deserve mention. Larry Audette has his own dyno--a homemade billet aluminum waterbrake with fully computerized instrumentation that was designed by a chainsaw racer pal of his. Besides having all of the readings you see here, Larry's dyno gives a BMEP reading at each step. His computer program has much better graphics than our SuperFlow. The reason he came here to test these engines was to compare his dyno readings to ours and, if the readings were similar, he wanted to have an independant test to brag about. The readings were nearly identical. And, we can brag about these engines for him.

First of all, the much maligned Indy Storm has stymied many savvy engine builders. The engine makes good torque and horsepower at low engine speeds, and performs great as a fast stocker or lightly modified low RPM performer. But until this one came along, no one around here has been able to achieve truly competitive Improved Stock horsepower in the big Fuji case reed engine.

Larry Audette of the CrankShop came up with this combination, which includes large amounts of epoxy on the outsides of the cylinders to facilitate the dramatic reshaping of the transfer ports. There is some question whether or not this would be acceptable in Improved Stock dragracing. While this engine's midrange horsepower was a bit lacking and surgy on the dyno, this is the first Storm engine we've seen even approach the magic 200 mark.

Helping achieve the 194 CBHP were V-Force reeds and cages that added 2-4 CBHP everywhere throughout the power band. Larry had 48mm CrankShop flatslide carbs on this engine as well. Stock crankcase volume, and stock ignition was used.

Our second Crank Shop special is a 925cc Mach-Open Improved Stock engine. This one uses 52mm CrankShop flatslide carbs. Stock reeds and reed cages are used on this one, though after seeing how they helped the 800 Storm mod, Larry is anxiously awaiting the arrival of some V-Force reeds for the Rotax triple to try at a later date on his own dyno.

For some reason, the 925 displacement mod engine makes more power than larger, longer stroke versions of this same modified engine.

Crank Shop Mod 800 Storm
48 Flatslide Carbs/580-560-560 mj/
V-FORCE REEDS-Open Pipes
Data for 29.92 in. Hg, 60 F dry air
Test: Terminal Control
Fuel Specific Gravity: .721
Vapor Pressure: .90
Barometer: 29.92

RPM	CBT	CBHP	FUEL	BSFC	CAT
8750	86.3	143.8	86.7	.73	80
9000	89.3	153.0	85.6	.59	81
9250	94.2	165.9	87.0	.56	81
9500	98.3	177.8	96.6	.58	81
9750	104.6	194.2	111.7	.61	80
10000	101.5	193.3	113.6	.62	81

Crank Shop Mod Mach Z
52 Flatslide Carbs/720-700-700 mj
Open Pipes
Data for 29.92 in. Hg, 60 F dry air
Test: Terminal Control
Fuel Specific Gravity: .721
Vapor Pressure: .90
Barometer: 29.92

RPM	CBT	CBHP	FUEL	BSFC	CAT
8000	104.2	158.7	86.6	.66	80
8250	107.9	169.5	86.6	.62	79
8500	110.9	179.5	86.5	.66	80
8750	117.2	195.3	86.8	.58	78
9000	123.5	211.6	87.0	.55	79
9250	123.6	217.7	86.5	.53	79
9500	118.5	214.3	85.5	.54	79

FEEDBACK

LEAVE OF ABSENCE

We're back! Sorry about that, guys. Debbie and I have been working full time on the turbo project since the last issue was sent to you in late spring. As many of you know, Greg Bennett and I teamed up with Gerhard Schruf and a growing group of stockholders to orchestrate the acquisition of Aerodyne Dallas, the Texas based manufacturer of the Aerocharger (R) turbocharger that we've been using on the First Choice Turbo systems.

Gerhard has been the operations manager of Aerodyne Dallas for about ten years. Aerodyne Dallas had spent 16 years and many millions of dollars perfecting and patenting the world's only self lubricating ball bearing turbocharger. When the opportunity for the acquisition arose last winter, Gerhard became a partner and stockholder with us. The facility will remain in Dallas, building Aerochargers and other components used in the First Choice Turbo systems.

Meanwhile, Debbie and I have been spending too much time with bookkeeping, accountants, attorneys, and potential investors, leaving us with little time for DynoTech. We're almost over the hump now, and I trust that it will be business as usual after October.

Meanwhile, in an effort to increase the annual volume of Aerochargers to the 1,000+ necessary for efficient production levels (we did 350 snowmobile systems last season), First Choice has developed a prototype SeaDoo GTX turbo that runs 11 MPH faster and accelerates much harder that stock. Those should be available to the public by the end of the calendar year.

The Harley Davidson Evolution engine was also addressed with an Aerocharger. The 1340cc four-stroke twin has been dramatically transformed by the Aerocharger- more than doubling the torque and horsepower on pump gas. The turbo comes on so quickly that it makes 8 psi of boost while blipping the throttle in neutral! High gear roll-on performance is better than any production motorcycle.

Our prototype Aerocharged FXR is a blast to ride--even for jaded afficionados of Oriental musclebikes like myself.

Al Unser Jr. rode the Aerocharged Harley when he was in nearby Buffalo for some public appearances. After his test ride, Al said "this thing is as quick as the Indy car in the first three gears, yet it rides and cruises like a stocker!". His reaction was like everyone else who has ridden it. He had to order one for his Harley Springer, one for his 670 Summit, and one for his SeaDoo GTX.

Look for a comprehensive article on the Aerocharged FXR (including a technical review by Kevin Cameron) in the November issue of Big Twins magazine.

SPEAKING OF FOUR-STROKES

There has been a lot of talk this year of four-stroke snowmobiles looming on the horizon. That may be the future for us, after the Environmental Protection Agency drops the hammer on recreational sources of air pollution. Outboard boat engines and snowmobiles are currently under scrutiny. One television news report on air pollution showed the visible cloud of oil smoke emitted from a large group of rental snowmobiles idling in West Yellowstone last winter. I would suspect that, unless the snowmobile manufacturers employ powerful, influential lobbyists, our polluting two-stroke engines will eventually be doomed.

The current state of Japanese four-stroke technology would indicate that we could expect only 120 CBHP per liter of engine displacement, with a substantial weight penalty to boot from clean-burning, four or more valve per cylinder high revving engines. A 75 CBHP 600cc four-stroke engine probably weighs more than a 900cc 160 CBHP two-stroke engine.

What will we do to regain some of our lost performance? Kevin Cameron suggests that doing a better job of putting the HP to the snow will pay great dividends. Check out TCD in this issue.

The four-stroke engines will present a whole new challenge for the performance-oriented snowmobiler. If they are anything like the current crop of Japanese sportbike engines, there won't be much left on the table by the engineers. Some years ago, I addressed the demise of the once huge motorcycle performance aftermarket industry in the 1990's after the public got smart.

Four-stroke snowmobiles will be a whole new, and fun ballgame. Once, I would have thought that losing half of our horsepower to the axe of the EPA would have been the end of the world for the performance snowmobilers. But now, we all should view

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that prospect as a new challenge that will eventually result in a superior performing product.

Snowmobiling today is like the "good-old days" of the late '60's, when car manufacturers satisfied the consumer by throwing piles of high emissions horsepower at buckboard chassis' that looked cool, but would pull maybe half a G on the skidpad and had brakes and tires that took a mile to slow down from a hundred and twenty, especially on the second "run".

When the musclecar party was ended by the EPA and the insurance industry in the early '70's, it began a new era of car manufacturers striving to put lower amounts of clean horsepower to the ground with improved suspensions, drivetrains, and tires. Today, twenty years later, those 14 second quarter mile times of the 60's musclecars make us yawn. Low emissions car performance today is much greater than that of the old junk we used to accept from Detroit. One ride today in a '60's or '70's big block anything will make you a believer in American Ingenuity. The performance cars (Corvettes, Camaros, Mustangs, Stealths, Vipers, etc.) of the mid '90's accelerate, handle, brake, and ride better, and get better fuel economy with less emmisions and noise than the "muscle cars" of the glory days. Air conditioning, good quality stereos, and power everything are included to boot. Sorry, old timers (me included). In retrospect, the air-polluting good-old-days were not that great.

The point is, the coming of the EPA axe is not necessarily a reason for us performance snowmobilers to commit mass suicide. We must have patience. Like us "old timers" who went into depression because, just as our student loans were paid off, and we could afford that new "muscle car", they were gone. It took a few years for them to return, but it was worth waiting for.

Will history repeat itself? Many of us suspect that it will.

A HORSEPOWERHOLIC HATES TO ADMIT THIS

But, I've become bored with halfs, ones and twos. So have a lot of you.

When I was young, it was fun to find a penny on the ground, knowing that four more would get me a Hershey bar. Today, I'll still pick up a penny out of principal, even though I know it will take 39 more to get a Hershey bar that now weighs about half of what the old five-center used to. The same scenario holds true with horsepower.

Remember the time I was excited after trying some different thickness fiber Phazer reed petals which enable us to pick up one horsepower? That was fun, going from 77 to 78 CBHP or whatever. Five years ago, when Tim Bender was trying to make a lowly 570 Exciter competitive in FIII racing, a half a HP was cause for celebration. Our then-new SuperFlow dyno was great for finding those tenths of a HP that would eventually add up to one. The ones would then add up to several. It was good fun.

Those days, the King of Stockers, the 650 Indy made 120+ CBHP with aftermarket pipes. Great fun then, but relatively mundane today.

Today's stock machines make so much horsepower that one or two more just don't make much of a difference. The V-Force reed cages that we tested on the T-Cat in this issue are a good example. They always seem to be good for 3-4 CBHP on any large displacement case reed engine that we try them on. That's big power. But, people who have tried them complain that they can't "feel the difference". You probably could have felt 3-4 CBHP on a Phazer, but on a mountain motor like a Thundercat, it doesn't seem to matter much, except to racers.

At times like this, having HP and torque reading out in tenths doesn't make much sense.

SPEAKING OF TORQUE

Several subscribers reported that we were once again under verbal attack from a magazine writer whose infatuation with engine torque output makes no sense to us, other than to act as a smokescreen covering up for a lack of horsepower on some things that he sells to the public.

This same guy is probably the one who said five years ago that we couldn't accurately test engines the way we do with a SuperFlow dyno. Computerized, instrumented dynos are no good. We don't know how to test. We spend our lives sitting at a dyno. Etc. Etc.

Torque is not "momentum", as this author reportedly said it was. Torque is only a force that does nothing on its own. It requires movement, or speed (RPM) to accomplish anything, or do "work". That work is measured as Horsepower. My spindley legs can exert 80 ft/lb of torque on the shaft of a bicycle pedal drive @ 40 RPM=.61 CBHP , but I'd hate to bet on myself in a race with a 5 ft/lb @ 6000 RPM Honda 50 step-through (5.7 CBHP).

Forget the smokescreen. Horsepower, and "backup horsepower" is what makes a snowmobile fast and easy to clutch.

BIG BORE VMAX 600

We promised you an article on Bender Racing's V-Max 600/ 700 nickasil big-bore. It proved to be unsuccessful, in that it produced literally the same airflow and horsepower as the "trailported" stock-bore cylinders. It is probable that the transfer ports, originally marginal on the 570 Exciter, are stretched beyond practical efficiency by boring the V-Max 600 out to 700cc. As you may recall, the last version of Bender's FIII Exciter race engine (130 CBHP 650cc stroker) had the entire crankcase widened to accomodate larger transfer ports.

STOCK EVALUATION
POLARIS XCR 600

This stock 1994 XCR 600 was brought to us by Kevin McClure of M&E Performance in West Valley, NY. It had the standard higher compression setup which gave us @135psi cranking pressure. There is an optional compression lowering shim that came with these sleds for those who might be unable to obtain decent quality fuel. There were 1200 reliable trail miles on the odometer.

Last year's XCR 600's used Yamaha-style coated steel-shim headgaskets that proved to be a source of complaints by some DynoTech subscribers. Coolant leaking into and out of the cylinders was not uncommon--a result, we suspect, of the thin diecast combustion chamber sealing surfaces flexing under load. On our Turbo XCR600, this showed up immediately. We solved that by the addition of billet heads with O-ring seals.

Polaris has reportedly rectified the problem for 1995 by increasing the thickness of the combustion chamber sealing surfaces.

The cast iron sleeved monoblock XCR 600 cylinder has much more radical port timing when compared to the XLT 580. The difference is as follows:

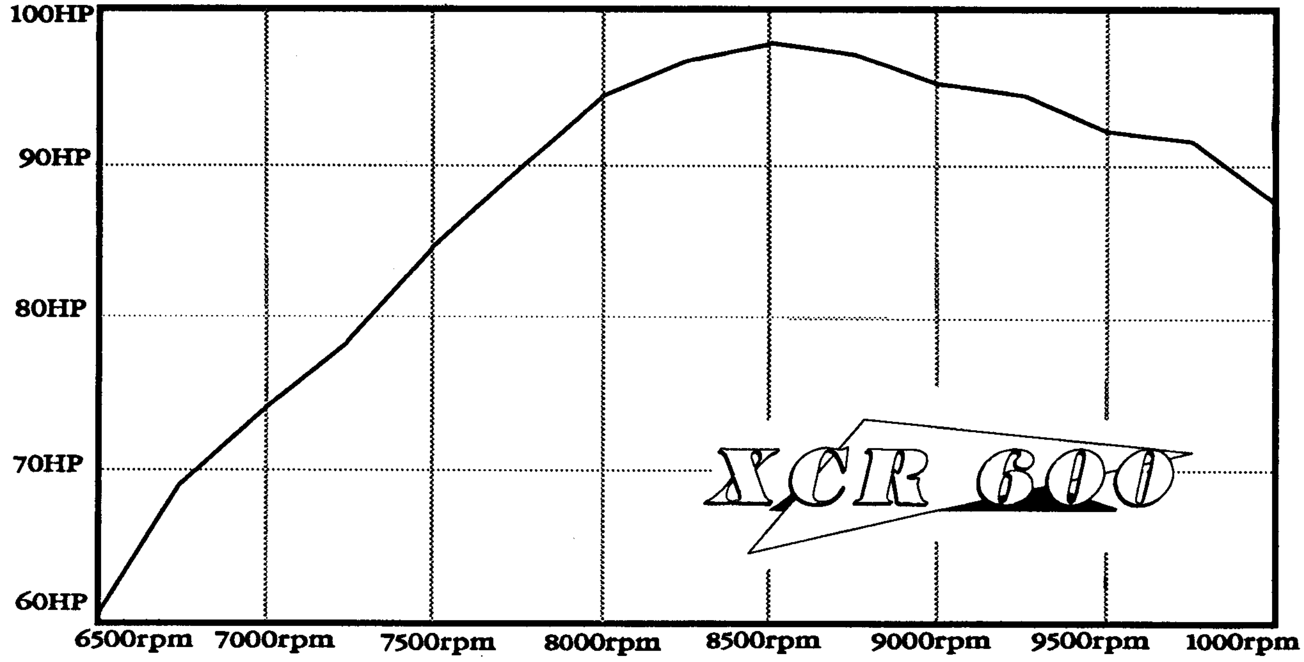
Exhaust port:	raised 1.5mm
Transfer ports:	raised 1.0mm
Intake port:	lowered 1.75mm

We normally don't test engines 1500 RPM past their power peaks, but this one had so much overrev power, we kept going until it showed signs of tailing off. This is a power band even I can clutch to.

This data was obtained with a hot pipe; the cool pipe gave us an 8250 RPM power peak, sliding up to the 8500 RPM peak observed here. Eventually (after, say, a minute at WOT), the power peak would slide up to 8750 or even higher. 230 main jets were perfect for 68 degrees .

1994 POLARIS 600 XCR
Data for 29.92 in. Hg, 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .741
Vapor Pressure: .12 Barometer: 29.58

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
6500	49.2	60.9	41.8	120.5	13.2	.70	68
6750	53.6	68.9	49.7	132.2	12.2	.73	67
7000	55.5	74.0	58.1	137.4	10.9	.80	68
7250	56.8	78.4	56.9	142.9	11.5	.74	68
7500	59.1	84.4	59.6	146.4	11.3	.72	68
7750	60.6	89.4	61.3	149.2	11.2	.70	67
8000	61.7	94.0	61.9	151.7	11.3	.67	67
8250	61.6	96.8	64.7	154.9	11.0	.68	66
8500	60.4	97.8	64.5	154.5	11.0	.67	67
8750	58.3	97.1	64.1	154.2	11.0	.67	68
9000	55.8	95.6	61.9	151.3	11.2	.66	68
9250	53.7	94.6	62.0	148.2	11.0	.67	68
9500	51.1	92.4	60.5	150.0	11.4	.66	66
9750	49.3	91.5	59.2	149.8	11.6	.66	67
10000	45.9	87.4	58.2	144.1	11.4	.68	67



ON SUSPENSIONS

THE CELLAR DWELLER

KEVIN CAMERON

The trail ahead looks rougher, not smoother and your arms and legs are just about at their limit from the hammering they've already taken. Now you hear another engine. As you turn your head to look, a competitor jets past--and he's sitting down with the skis and track under him undulating easily! You forget this as you prepare for punishment from the next series of whoops.

Later you think about what you've seen. While you've been killing yourself, using your arms and legs as a human suspension, that other rider has somehow managed to make his suspension do the job. How?

This is the question more and more riders are asking. After exciting years of horsepower buildup, the real performance gains have grown thin. For some (our hypothetical rider above), performance has stagnated. But others have switched their attention from engines to chassis--and they are pulling rapidly away from the rest of us.

This is a situation that has been repeated in every branch of motorsport, time and again. In the early days of auto racing, engines quickly became huge and powerful, requiring heavy chassis and giant tires to carry them. Only men with arms like legs could control such machines as the 1908 Grand Prix Mercedes. Then a smaller class was added, with engine size limited. The small engines forced designers to consider other ways to go fast--and they hit upon chassis and suspension development. Soon, they were so much faster than the big class that it was discontinued.

In the 1950's Ferrari used high revs and valve area to get almost 300 horsepower from its 2500 cc V12, while the tiny Cooper team, with only 240 horsepower available from its low revving Climax four, had no way to match them. Or did they? Cooper pioneered the rear engined car, with fully independent suspension, and they walked all over their competition. Soon, everyone was building such cars.

In motorcycle racing, 150 horsepower 1025cc Superbikes put on a great show of sliding, wobbling and leaping as their riders struggled to stay aboard in the late 1970s and early '80s. Today muffled street 600 machines easily eclipse their records--and they do it without all the fuss. Why? Today's bikes have improved chassis and sophisticated dampers.

Obvious parallels exist on snow and ice--even in a straight line. Dynotech's own Jim Czekala recently had the experience of being unable to stay with a 160 horsepower sled, while riding his 200 horsepower turbo V-Max 4--in a straight sprint on Grand Lake in the Colorado Rockies. The other man's suspension was putting power to the ice, but Jim's was just chattering and making a beautiful roostertail of fog and slush.

What if there were a way to go faster with a smaller engine and a smaller sled--and to do it sitting down? Today's sleds have grown fat to provide a foundation for ever-bigger, heavier engines. All this weight growth means that when you go really fast on the trails, you look like Christian Lautenschlager come back to life on his 1908 Mercedes, sweating, sawing at the controls, two-thirds out of control, and exhausted.

We're all aware of the trick, long travel suspensions that tuners and manufacturers are testing and releasing now. We're also aware that just having such a suspension isn't the same as making it work.

Racing motorcycles were in this same position in 1980. They were powerful, they were fast in a straight line, but exhausting to ride. Long travel suspension helped--some--but it was no cure-all. When they got onto rough surfaces, they went crazy--the chassis flexing and juddering, the tires sliding unpredictably, first at the front, then at the back. It was like the "speed up and die" part of one of those "slow down and live" commercials.

Let's consider suspension. The minimum system is no suspension--no spring, no damper. A rigid ski hits a whoop, and the whole front of the sled is driven upward at whatever vertical speed the bump gives it. At the top of the bump, the ski flies up in the air, where it gets no grip at all. Whenever gravity gets around to it, the front of the sled falls back to

ON SUSPENSIONS

THE CELLAR DWELLER Continued

earth and the operator can resume trying to steer--if the initial impact hasn't orbited him right off the sled.

This is terrible, both because of the violent impact and the momentary loss of grip and control. In a blaze of inspiration, we invent springs. Now when the ski hits that same bump, it is driven upwards with the same violence as before--but the front of the sled is not.because the spring compresses somewhat, allowing the sled to rise by a much smaller amount. Through the flexibility of the spring, the hard smash of the bump is transmitted as a much softer push to the sled. The rider is not knocked off, which is another plus.

But the ski still flies up off the snow as the bump passes under it, losing its grip as before, then snapping back down a moment later. And because the spring has still given the sled some upward push, it rises momentarily, then settles back, rebounds off the spring, rising and falling like the familiar car with bad shocks, hitting a big bump. All this plunging up and down causes a wide variation in the skis' pressure on the ground--and in their grip. If you hit this bump in a corner, the result will be repeated episodes of partial loss of steering control as the sled nods up and down.

Again comes the brilliant flash of invention. We add friction to our system, to eat up the bump energy that will otherwise cause our machine to oscillate after every bump. In the old days, this friction was generated by clutch-like discs, scrubbed against each other by suspension action, acting through scissors linkage. With just the right adjustment, when we hit our favorite bump, this spring saves us from the hard upward blow, and the friction device (properly called a damper) saves us from continuing to oscillate afterwards.

But there's fresh trouble. If the damper is just right for a bump hit at high speed, there is much too much friction at low speed, and the ride is harsh. Or, if it's right at low speeds, there's too little damping at high speed. Ideally, damping force should rise in proportion to speed, so that at all speeds, bump motions will be damped out quickly, and our sled won't be overly harsh or oscillate.

One kind of damping that increases with speed is fluid friction. We build a kind of pump--a sealed cylinder with a piston inside it, linked so suspension movement drives the piston back and forth through the fluid. We put an orifice through the piston. Now when the suspension pushes the piston, it resists the motion because it takes pressure to force the fluid back and forth through the orifice. To get more damping force, we make the orifice smaller, and vice versa.

But there is more trouble. The resistance of this device does increase with increasing suspension velocity--but not in direct proportion. It increases as a square of the speed. Therefore if we size the orifice to get correct damping at say, 45 mph, then at twice that speed, instead of twice the damping force, we get four times as much. When at 90 mph we hit a bump that was comfortably absorbed at 45 mph, the damping force is now so high that a sharp bump knocks us off our sleds.

The fix for this was to provide a variable damping orifice, one that got bigger as the pressure across it increased with increasing suspension velocity. We put a lid on the orifice, held shut by a spring. As we hit harder and harder bumps, pressure across this orifice rises, lifting the lid more each time. In this way, an approximately linear (in straight proportion) response to bumps of various vertical velocities could be achieved--within limits.

Naturally, there have to be separate valving systems for the two suspension movements--compression and rebound--because the fluid moves two ways through the piston.

A DETAIL OF CONSTRUCTION

Another detail is that the piston rod, in order to move into the cylinder on the compression stroke, must push out some fluid; oil is not compressible. To permit this, the damper cylinder is surrounded with a second, outer tube that is normally half full of damper oil, half full of air. Using the compression stroke, the oil displaced from the inner, damper cylinder passes through the so-called "foot valve" at the bottom of the cylinder (this valve may also incorporate the compression damping function). As this displaced fluid is driven out into the outer tube, the fluid level there rises somewhat, and the air above it (called the clearance air) is slightly compressed. This keeps the inner tube full of oil, and the compressible air in the outer tube allows the damper rod to be pushed into the cylinder. This type of damper cannot be operated on its side or upside-down because the clearance air will then enter the inner tube and make the damper oil foamy and springy. When such a damper lies on its side for a time and does get air in its inner tube, a few strokes in the upright position (rod up, body

THE CELLAR DWELLER Continued

down) will pump the air back into the outer tube for normal operation.

For motorsports use, the double tube damper is useless because the violence of maneuvers and rapidity of damper stroking inevitably mix the oil and outer tube clearance air, making the oil foamy and drastically reducing its damping. Such a damper may work well for a lap or two, then handling mysteriously deteriorates as the air and oil form an emulsion.

Some damper builders try to make a virtue of this by building so-called emulsion dampers. In these a single tube is used, and no attempt is made to separate the oil from the necessary clearance air. To restore the damping lost in the dilution of the oil by billions of tiny air bubbles, the damping orifices are simply made smaller. This solution, though inexpensive to build and clever in concept, has not survived in the marketplace.

The elegant solution is the gas-pressurized damper, often built with a remote reservoir. A single tube is used as the damper cylinder, and the oil displaced from it as the damper rod enters it is conducted away through a pressure hose to the remote reservoir, where the compression valve is often located. This reservoir is really what the hydraulics people call an accumulator. This reservoir cylinder is about 2/3 full of oil, 1/3 full of compressed nitrogen gas.

The oil and gas are separated by a sliding, O-ringed piston so they can never mix.

Why pressurize the reservoir? When the damper piston moves back and forth very rapidly, it can produce a powerful vacuum, first on one side of the piston, then on the other. This can actually pull the piston apart, which is called cavitation. This liberates gases dissolved in the oil, leading to foaming, and the production and collapse of the cavitation bubbles does violence to the damping process. Pressurizing the system almost entirely does away with this.

Why nitrogen gas, rather than air, or whatever you may have under pressure in your shop? Nitrogen is inert, but air or oxygen, suddenly in contact with hot damper oil when a seal fails, constitutes a potent bomb that has injured those ignorant enough to ignore the use of nitrogen. Nitrogen only! Typical accumulator pressures are around 275 psi.

All this tech history brings us up to about 1980. At this point, in the sport of motocross, suspension engineers, irked by the constant complaints of riders, looked deeper yet. It had always been assumed that damper motions were relatively slow. Damper test machines were ponderous affairs that stroked the units up and down at one or two cycles per second. The engineers would size and tune their orifices to get the machine to draw "perfect" damping curves, and then the test riders would go out and get kicked on their asses. No one could figure it out.

Measurements made by Honda (among others) revealed piston velocities on motocross dampers of as high as 13 feet per second. When a test machine to produce such speeds was built, it was found that damping force at such speed was essentially infinite. So that was it. That was why damper rods kept breaking, even when they were made bigger and bigger. That was why riders complained and fell off so much. That was why a "perfect" damping curve on a low speed damper test machine did not translate to good track performance.

THE AWFUL DETAILS

Here is what was happening. Dampers were then built with compression valves having the following elements;

(1) a low speed orifice. This was a fixed orifice, provided to allow low-speed motion

(2) a variable orifice. This was an orifice or set of orifices, covered by a spring-backed washer.

This set-up worked like this. As piston speed increased from zero, the fixed low-speed orifice gave damping that increased as the square of the speed, but before damping force could rise too high, the spring-backed washer would begin to lift, exposing extra orifice are, thereby limiting the rate of damping force increase. As piston speed increased more and more, the washer would rise higher. But finally came the real problem. At some moderately high damper velocity, the washer would have lifted so far that the orifices under it were the limiting factor. Now further increases in damper piston velocity again caused a velocity-squared rise in damping force--essentially the force went straight up to infinity at this point; the damper had become rigid. It was this very high

ON SUSPENSIONS

THE CELLAR DWELLER Continued

damping force that was bending and breaking the damper rods, making bikes judder and hop, and putting people on the ground.

The modern damper avoids all this by providing enough variable-orifice area to keep the damper's resistance force proportional to velocity even at very high damper speeds. The primary technology for this is the washer stack. Instead of the old spring-back washer covering the orifices, in the new technology, the washer itself becomes the spring. It covers a ring of orifices, but is held down against them only at its center. As pressure rises, the washer is lifted at its outer edge by the oil pressure under it, deforming into a flat cone shape. Naturally the OD of the washer is smaller than that of the damper cylinder, to allow fluid to flow around it.

The response of the orifices to varying pressures tailored to the application by stacking washers and spacers of various thicknesses over the orifices. By varying the thickness of the washer, or by stacking more than one, the amount of damping in a particular speed range can be changed. If it's desired to increase damping at a higher speed, the first washer can be backed with a thin spacer, backed in turn by a thicker washer. Thus, as the first washer deforms more and more under increasing pressure, it will eventually cone up far enough to contact the thicker washer, stiffening its resistance to further speed increases.

An alternative technology uses an array of orifices, each one capped by a spring-backed ball. By varying the spring thicknesses and pre-loads, a variety of damping curves can be created.

So far we have concentrated on the compression stroke because the problems with it were the cause of the poor performance of traditional "door closer" dampers. But because of the upsetting nature of compression forces on vehicles, most of the damping is performed on the rebound stroke. Compression damping exists to prevent the ski or track from overshooting the top of the bump and "getting air time" and to prevent bottoming. The goal in compression damping is to provide damping proportional to piston velocity, and it is a major tool of the suspension tuner.

HOW A MODERN DAMPER IS CONSTRUCTED

These modern externally adjustable dampers seem like just the thing. Call and order, no matter what the price. You get the goods red label and can't wait to bolt these beauties on. You try 'em, then set the damping to your preference and expect miraculous actions, but...it's not that simple. The adjuster knobs adjust only the low-speed orifices--not the action of the washer stacks. If you want a little more or less damping overall, the adjusters will provide that trimming action. But, if you have, just as an example, too much high-speed compression damping, clicking the adjuster to the lowest setting will have no effect at all. The damper will have to be de-pressurized, disassembled, and fitted with a revised washer stack to make a real change in its high-speed compression action. This is why you see the box vans of the major damper makers at motocross or road race events, with hard working technicians up inside them, referring to charts as they select and stack washers, refit and refill bodies, and pressurize complete units. They are attempting to translate the comments and complaints of riders into improved damping curves.

This, in outline, is why you can be out there on that trail, beaten to a pulp by the hammering of your sled's harsh suspension, and another rider on the same kind of sled, even perhaps with the same trendy brand of dampers, can come past you like greased lightning, sitting down, smiling, and full of concentration and energy.

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