Volume 1 Number 6 1989

DYNOTECH

THE SNOWMOBILE PERFORMANCE PUBLICATION

PIPE SHOOTOUT #7

STOCK 1989 MACH I

Present during test: Jim Czekala, Gary "Dr" Polyok, Mike "Herbie" Golec, & Dan Jenkins.

For our 7th Pipe Shootout we used a stock 1989 Mach I engine provided by Dan Jenkins. The engine, pulled from a sled Dan had in stock, was broken in with 2000 trail miles and delivered slightly more power than the brand new stocker that we tested in issue #2.

All of the pipes were tested with an airbox that Bombardier had modified for Dan's "tuned up" engine (see accompanying article). Because two additional 1.75" holes had been drilled in the box, airflow readings were unavailable. Also included in our data are the tests we ran with the stock, Decker, and FAST pipes using K&N filters. We used the large K&N filters (as pictured in issue #5 page 3) that, when clean, have virtually no effect on fuel flow when compared to open 38mm carbs.

LL av gas was used throughout testing, and the oil injection was left functional. We attempted to keep our BSFC safe--as close to the mid sixties as possible. **Our jet spec is for 80 degree F, at sea level.**

The results of this dyno evaluation are remarkably different from our Modified Mach 1 Pipe Shootout in issue #5. Subtle differences in rotary valve and port timing, carburetion, and compression in the Mach 1 dramatically affect the way the pipe(s) perform on the engine. This emphasizes the benefit people derive from testing and "dialing in" their engines at our facility, or trying out various aftermarket pipes before making a purchase.

There are only subtle differences in port timing between the 1989 and 1990 Mach 1. When we tested the identical pipes on our 1990 engine, the only positive results were with the FAST twin pipes (8 CBHP increase over stock @ 8250 RPM).

The short, high RPM PPP pipes haven't worked well on any of the Mach 1 engines we have tested so far. However, we are bringing in a full mod (similar to the FIII spec) Mach 1 engine for another Pipe Shootout soon, and the PPP pipes should be a better match for it.

The 1990 stock Mach 1 will be retested in a future issue, after all of the new pipes are ready.

Finally, my thanks to Dan and Gary, who probably made 50 jet and pipe changes out in the hot, sticky dyno room while I operated the computer in the air conditioned control room.

STOCK PIPE 260-290 MJ
STOCK 1989 AIRBOX 86 dB
Data for 29.92 inches Hg, 60 F dry air.
TEST: 100 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .700
VAPOR PRESSURE: .82
BAROMETRIC PRESSURE: 30.28

RPM	CBT	CBHP	FUEL	BSFC	CAT
6500	65.5	81.1	56.8	.73	78
6750	67.1	86.2	59.8	.72	77
7000	68.0	90.6	62.9	.72	76
7250	67.3	92.9	63.8	.71	78
7500	63.5	90.7	63.4	.73	79
7750	54.7	80.7	64.2	.83	78

STOCK PIPE 290-310 MJ
IMPROVED AIRBOX 86 dB
Data for 29.92 inches Hg, 60 F dry air.
TEST: 100 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .700
VAPOR PRESSURE: .82
BAROMETRIC PRESSURE: 30.29

RPM	CBT	CBHP	FUEL	BSFC	CAT
6750	69.7	89.6	55.6	.64	78
7000	69.9	93.2	55.0	.61	78
7250	69.8	96.4	57.6	.62	77
7500	67.5	96.4	61.0	.66	78
7750	59.2	87.4	60.3	.72	78

PIPE SHOOTOUT #7

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AAEN SINGLE PIPE 290-310 MJ
IMPROVED AIRBOX 88 dB
Data for 29.92 Inches Hg, 60 F dry air.
TEST: 100 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .700
VAPOR PRESSURE: .82
BAROMETRIC PRESSURE: 30.28

RPM	CBT	CBHP	FUEL	BSFC	CAT
6750	63.8	82.0	50.2	.64	81
7000	65.2	86.9	53.1	.64	81
7250	65.8	90.8	53.7	.61	80
7500	65.3	93.3	56.4	.63	79
7750	64.4	95.0	57.8	.63	80
8000	61.5	93.7	58.6	.65	80

FORMULA PLUS PIPE 290-310 MJ
IMPROVED AIRBOX No dB
Data for 29.92 Inches Hg, 60 F dry air.
TEST: 100 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .700
VAPOR PRESSURE: .82
BAROMETRIC PRESSURE: 30.28

RPM	CBT	CBHP	FUEL	BSFC	CAT
6750	60.6	77.9	46.3	.62	79
7000	63.8	85.0	49.1	.60	79
7250	64.8	89.5	51.3	.60	79
7500	64.7	92.4	54.8	.62	80
7750	64.0	94.4	57.9	.64	79
8000	61.8	94.1	59.6	.66	80

DECKER TWIN PIPES 270-290 MJ
IMPROVED AIRBOX 96 dB
Data for 29.92 Inches Hg, 60 F dry air.
TEST: 100 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .700
VAPOR PRESSURE: .82
BAROMETRIC PRESSURE: 30.26

RPM	CBT	CBHP	FUEL	BSFC	CAT
6500	64.6	80.0	51.5	.67	82
6750	63.6	81.7	54.5	.70	83
7000	64.3	85.7	53.6	.65	82
7250	65.4	90.3	54.6	.63	82
7500	65.2	93.1	57.1	.64	81
7750	65.3	96.4	57.2	.62	81
8000	66.3	101.0	60.4	.62	82
8250	63.0	99.0	63.7	.67	82

PRECISION PROD TWIN PIPES 290-310 MJ
IMPROVED AIRBOX No dB
Data for 29.92 Inches Hg, 60 F dry air.
TEST: 100 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .700
VAPOR PRESSURE: .82
BAROMETRIC PRESSURE: 30.25

RPM	CBT	CBHP	FUEL	BSFC	CAT
6000	47.9	54.7	39.6	.76	83
6250	52.6	62.6	42.8	.71	83
6500	53.3	66.0	44.5	.71	84
6750	53.7	69.0	48.8	.74	84
7000	58.1	77.4	48.9	.66	83
7250	60.2	83.1	52.1	.66	83
7500	60.6	86.5	53.5	.65	82
7750	60.4	89.1	57.8	.68	82
8000	58.2	88.7	57.5	.68	83
8250	56.0	88.0	58.9	.70	84
8500	53.4	86.4	59.0	.72	83

STOCK PIPE 310-330 MJ
K&N FILTERS
Data for 29.92 Inches Hg, 60 F dry air.
TEST: 100 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .700
VAPOR PRESSURE: .82
BAROMETRIC PRESSURE: 30.25

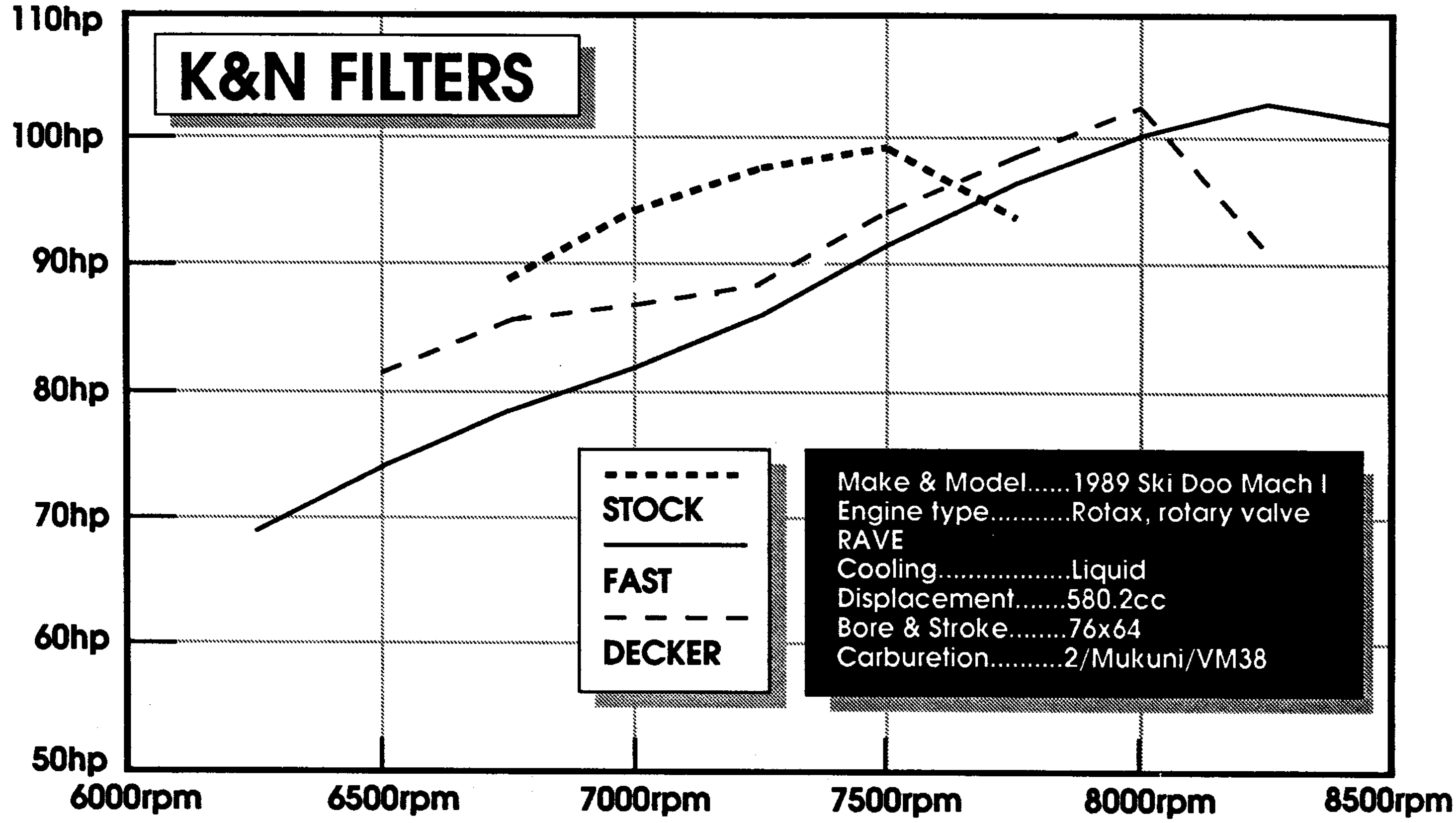
RPM	CBT	CBHP	FUEL	BSFC	CAT
6750	69.3	89.1	51.9	.61	84
7000	70.8	94.4	52.2	.58	84
7250	70.9	97.9	53.1	.57	84
7500	69.9	99.8	55.5	.58	84
7750	63.9	94.3	55.5	.62	84

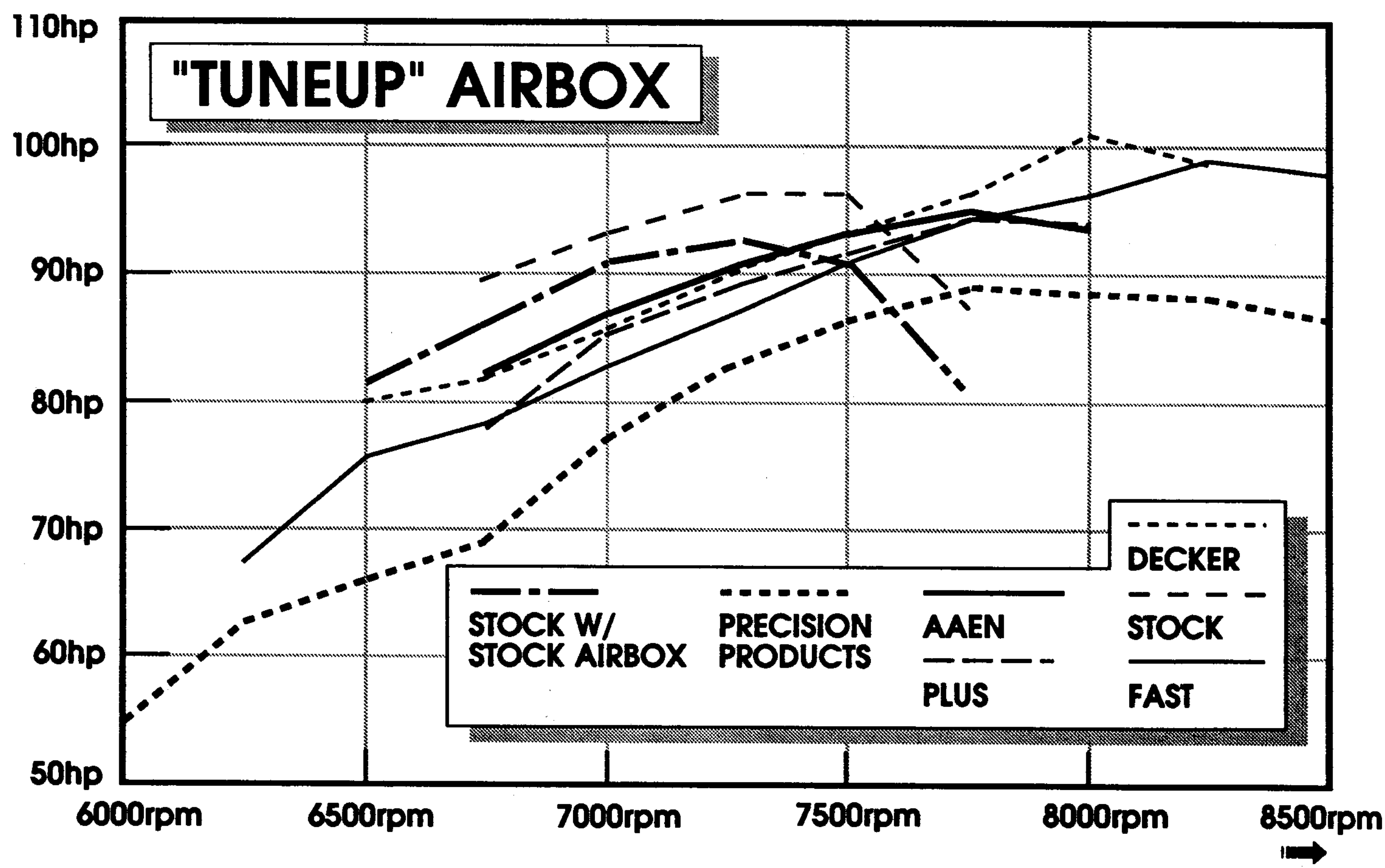
DECKER TWIN PIPES 290-310 MJ
K&N FILTERS
Data for 29.92 Inches Hg, 60 F dry air.
TEST: 100 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .700
VAPOR PRESSURE: .82
BAROMETRIC PRESSURE: 30.27

RPM	CBT	CBHP	FUEL	BSFC	CAT
6500	66.1	81.8	53.7	.69	85
6750	66.9	86.0	55.8	.68	85
7000	66.5	86.6	58.8	.70	86
7250	63.6	87.8	55.9	.67	86
7500	66.2	94.5	55.3	.61	84
7750	67.0	98.9	56.9	.60	85
8000	67.5	102.8	59.2	.60	86
8250	58.2	91.4	64.9	.74	84

PIPE SHOOTOUT #7

Continued from page 2





PIPE SHOOTOUT #7

Continued from page 3

FAST TWIN PIPES 290-310 MJ
K&N FILTERS
Data for 29.92 Inches Hg, 60 F dry air.
TEST: 100 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .700
VAPOR PRESSURE: .82
BAROMETRIC PRESSURE: 30.26

RPM	CBT	CBHP	FUEL	BSFC	CAT
6250	57.7	68.7	48.8	.74	83
6500	60.3	74.6	51.2	.72	83
6750	61.2	78.8	53.5	.71	85
7000	61.6	82.1	56.0	.71	85
7250	62.7	86.6	55.7	.67	85
7500	64.3	91.8	55.8	.64	85
7750	65.6	96.8	55.9	.60	84
8000	65.9	100.4	57.4	.60	84
8250	65.7	103.2	59.9	.61	84
8500	62.7	101.5	61.5	.64	84

FAST TWIN PIPES 270-290 MJ
IMPROVED AIRBOX 96 dB
Data for 29.92 Inches Hg, 60 F dry air.
TEST: 100 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .700
VAPOR PRESSURE: .82
BAROMETRIC PRESSURE: 30.26

RPM	CBT	CBHP	FUEL	BSFC	CAT
6250	56.0	66.6	46.0	.72	83
6500	60.8	75.2	48.7	.67	81
6750	61.0	78.4	52.7	.70	82
7000	62.2	82.9	52.7	.66	83
7250	63.1	87.1	51.5	.62	84
7500	64.1	91.5	54.5	.62	83
7750	64.1	94.6	57.7	.64	83
8000	63.3	96.4	57.1	.62	83
8250	63.1	99.1	58.6	.62	83
8500	60.6	98.1	58.0	.62	80

"FACTORY TUNE-UP"

1989 MACH 1 "FACTORY TUNE-UP"

In early August, Dan Jenkins (owner of J&J Sales and Service Yamaha and Ski-Doo dealership in Huron, Ohio, 419-433-2523) came here to dyno test one of several 1989 Mach engines that the Bombardier factory had modified late last season at their facility in Wausau, WI. We were amazed to see the engine make 101 CBHP with the stock carbs and pipe. Bombardier is apparently offering a similar warranty "tune-up" this year to 1989 Mach 1 owners who are unhappy with the performance of their sleds. The factory tune-up includes the engine updates listed below, in conjunction with some chassis improvements that will reduce friction and increase top speed.

We thought that the warranty situation and impressive performance increase over the stock '89 engine, justified a closer examination of the modifications.

After completion of our pipe shootout, We took Dan's completely stock 1989 Mach 1 engine, and performed the factory tune-up on it, one step at a time, to determine the effect of each modification on engine performance.

The tune-up consists of a modified airbox (two 1.75" holes drilled in the box near the air horns in the baffle), larger 340-360 main jets, an opposite stagger on the needle jets (P4-P2), a 209 rotary valve, removing .010" from the head (or, whatever it takes to achieve a .050" squish), and opening the outlet of the single pipe from 30 to 32mm. Opening the outlet of the pipe 2mm evidently reduces the heat buildup in the engine, allowing the use of 92 octane fuel. It also should allow the RAVE to open a little later, because of the reduced backpressure. Shortening the Y-pipe 1/2" at the cylinder junctions evidently will not be included free of charge in the tune-up, but should be a fairly inexpensive project for your local welding shop. The trade-off is some mid-range power for a little more CBHP at a slightly higher RPM.

FACTORY "TUNE-UP"

Continued from page 4

When we tested the engine with the improved airbox, we adjusted the jetting down, according to our Mikuni calculator, to 290-310 to compensate for the mid-eighty degree F humid air during our test session. Note that as the horsepower increased with each component change, our BSFC dropped into the high .50's. Shortening the Y pipe probably should be accompanied by one size larger main jet to be safe.

Mach 1 owners who opt for this "tuneup" will obviously be rewarded with much greater performance. Please be aware that the factory jet spec is quite close, and jet changing will be necessary when air density increases.

In our next issue we'll compare the tuned up 1989 engine with the stock 1990 engine.

STOCK 1989 MACH 1 (winter jets)
Data for 29.92 inches Hg, 60 F dry air.
TEST: 100 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .700
VAPOR PRESSURE: .82
BAROMETRIC PRESSURE: 30.28

RPM	CBT	CBHP	FUEL	BSFC	CAT
6500	65.5	81.1	56.8	.73	78
6750	67.1	86.2	59.8	.72	77
7000	68.0	90.6	62.9	.72	76
7250	67.3	92.9	63.8	.71	78
7500	63.5	90.7	63.4	.73	79
7750	54.7	80.7	64.2	.83	78

INSTALL IMPROVED AIRBOX AND 290-310 JETS
Data for 29.92 inches Hg, 60 F dry air.
TEST: 100 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .700
VAPOR PRESSURE: .82
BAROMETRIC PRESSURE: 30.29

RPM	CBT	CBHP	FUEL	BSFC	CAT
6750	69.7	89.6	55.6	.64	78
7000	69.9	93.2	55.0	.61	78
7250	69.8	96.4	57.6	.62	77
7500	67.5	96.4	61.0	.66	78
7750	59.2	87.4	60.3	.72	78

INSTALL 209 ROTARY VALVE
Data for 29.92 inches Hg, 60 F dry air.
TEST: 100 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .700
VAPOR PRESSURE: .82
BAROMETRIC PRESSURE: 30.29

RPM	CBT	CBHP	FUEL	BSFC	CAT
6750	69.5	89.3	49.5	.58	86
7000	70.5	94.0	53.5	.60	86
7250	70.5	97.3	55.9	.60	86
7500	68.2	97.4	58.2	.63	86
7750	62.7	92.5	60.3	.68	86

CUT HEAD SURFACE .010
Data for 29.92 inches Hg, 60 F dry air.
TEST: 100 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .700
VAPOR PRESSURE: .82
BAROMETRIC PRESSURE: 30.23

RPM	CBT	CBHP	FUEL	BSFC	CAT
6750	71.2	91.5	53.5	.61	86
7000	72.8	97.0	56.0	.60	86
7250	72.1	99.5	55.5	.58	86
7500	68.7	98.1	59.3	.63	86

SHORTEN Y PIPE 1/2"
Data for 29.92 inches Hg, 60 F dry air.
TEST: 100 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .700
VAPOR PRESSURE: .82
BAROMETRIC PRESSURE: 30.21

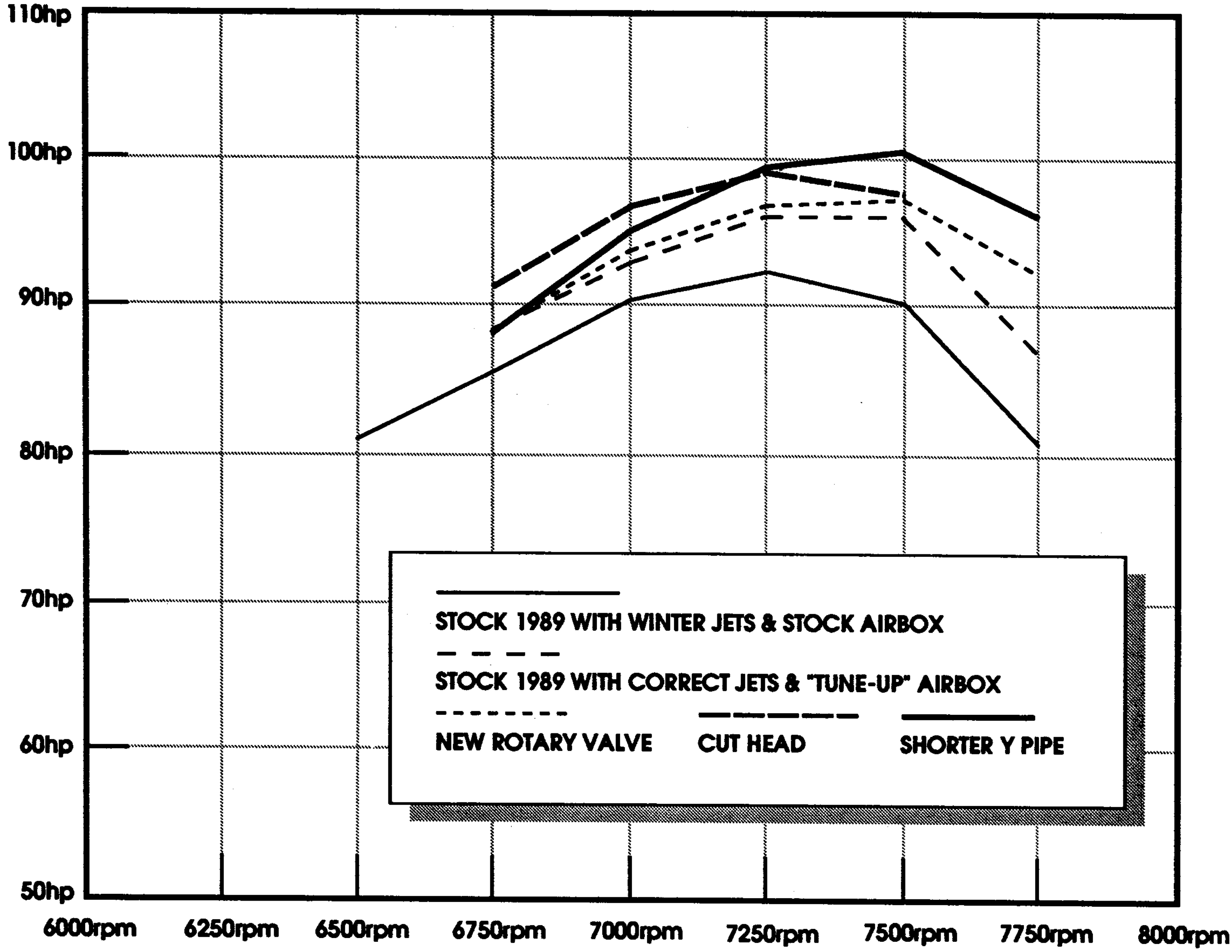
RPM	CBT	CBHP	FUEL	BSFC	CAT
6750	69.2	88.9	50.8	.60	84
7000	71.7	95.6	53.4	.58	83
7250	72.2	99.7	53.9	.56	83
7500	70.9	101.2	54.8	.57	83
7750	65.1	96.1	59.9	.65	83

OPEN TUNED PIPE OUTLET TO 32MM
Data for 29.92 inches Hg, 60 F dry air.
TEST: 100 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .700
VAPOR PRESSURE: .82
BAROMETRIC PRESSURE: 30.21

RPM	CBT	CBHP	FUEL	BSFC	CAT
6750	67.7	87.0	49.2	.59	84
7000	70.8	94.4	53.3	.59	83
7250	71.3	98.4	54.1	.57	83
7500	70.4	100.5	57.2	.60	83
7750	65.1	96.1	60.0	.65	83

FACTORY "TUNE-UP"

Continued from page 5



DYNO TERMINOLOGY REFRESHER

RPM: Engine crankshaft speed.

CBT: Corrected Brake Torque. The expected twisting force that the crankshaft would exert at sea level, 60 degree dry air.

CBHP: Corrected Brake Horsepower. The expected horsepower, or ability of the engine to do work at sea level, 60 degree dry air.

FUEL: Actual fuel flow into the engine in POUNDS PER HOUR.

AIR: Airflow through the engine in STANDARD CUBIC FEET PER MINUTE.

A/F: Air/Fuel ratio. The number of pounds of air the engine uses for every pound of fuel. 10-1 is rich and 20-1 is lean.

BSFC: Brake Specific Fuel Consumption. Pounds of fuel used per horsepower per hour. .70 is rich, lazy and safe. .50 is lean, on the edge, maximum power on most two-stroke engines. Our BSFC readout is perhaps our most valuable tuning tool.

CAT: Carb Air Temperature.

1989 EL TIGRE 6000

Make & Model......1989 Arctic Cat El Tigre 6000
Engine type...........Case reed twin
Cooling..................Liquid
Displacement........529cc
Bore & Stroke..........72x65
Carburetion...........2/Mikuni/vm38
Exhaust..................Twin w/single canister

Cat enthusiast Greg Hennel, of Schenectady, N.Y. (518-374-0035) brought us two 530cc engines upon which we made our dyno evaluations. The first was a completely stock 1989 El Tigre 6000. Greg had ported the other engine according to the Arctic 530 mod specs that were released with the 1988 FIII 650 specs, and had removed .030" from the heads, leaving a .055" squish. He was interested in the difference the Arctic Mod Porting Specs would make when applied to this engine, and so were we.

The first set of data is from the stock engine, with the main jets reduced to 350 to compensate for the 40 degree F carb air temp (CAT).

BASELINE STOCK ENGINE
Data for 29.92 inches Hg, 60 F dry air.
TEST: 100 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .700
VAPOR PRESSURE: .15
BAROMETRIC PRESSURE: 30.19

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
6500	45.7	56.6	47.4	141.6	13.7	.78	39
6750	47.6	61.1	45.3	144.6	14.7	.69	40
7000	48.8	65.0	48.3	147.2	14.0	.69	40
7250	49.3	68.0	52.1	150.3	13.2	.72	40
7500	47.9	68.5	52.8	153.3	13.3	.72	38
7750	48.0	70.9	53.6	156.4	13.4	.71	38
8000	48.1	73.2	53.8	158.6	13.5	.68	39
8250	48.0	75.3	55.8	159.3	13.1	.69	39
8500	46.1	74.6	56.6	159.6	12.9	.71	40
8750	37.2	62.0	59.5	155.0	12.0	.89	39

PHASE 1. Next, we setup the second engine, which Greg had modified as closely as possible according to Arctco's published mod specs. Larger 40mm carbs were installed with 390 mains, and the airbox was eliminated. The stock exhaust system was retained.

PHASE 1 DATA
ARCTIC MOD PORT SPECS
40MM CARBS, 390 MJ STOCK EXHAUST
Data for 29.92 inches Hg, 60 F dry air.
TEST: 100 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .700
VAPOR PRESSURE: .82
BAROMETRIC PRESSURE: 30.21

RPM	CBT	CBHP	FUEL	BSFC	CAT
6750	49.7	63.9	45.0	.68	37
7000	51.3	68.4	50.4	.71	37
7250	53.2	73.4	53.2	.70	37
7500	55.6	79.4	57.7	.70	37
7750	57.4	84.7	58.0	.66	38
8000	58.7	89.4	62.8	.68	36
8250	52.3	82.2	63.8	.75	36

PHASE 2. To demonstrate the difference resulting from leaner jetting, we dropped to 350 mains. **A BSFC this low should require *100 octane fuel.***

PHASE 2 DATA
ARCTIC MOD PORT SPECS
40MM CARBS, 350 MJ STOCK EXHAUST
Data for 29.92 inches Hg, 60 F dry air.
TEST: 100 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .700
VAPOR PRESSURE: .15
BAROMETRIC PRESSURE: 30.21

RPM	CBT	CBHP	FUEL	BSFC	CAT
6750	49.0	63.0	41.2	.63	36
7000	51.2	68.2	43.5	.62	37
7250	52.7	72.7	47.3	.63	36
7500	55.6	79.4	51.6	.63	36
7750	58.4	86.2	54.2	.61	37
8000	60.6	92.3	55.6	.58	36
8250	58.4	91.7	58.9	.62	36

PHASE 3. Installing a set of pipes shortened according to the factory mod specs and stock canister raised the power peak 500 RPM, but had little effect on the CBHP.

1989 EL TIGRE 6000

Continued from page 7

PHASE 3 DATA
ARCTIC MOD PORT SPECS
40MM CARBS, 350 MJ, MOD EXHAUST
Data for 29.92 inches Hg, 60 F dry air.
TEST: 100 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .700
VAPOR PRESSURE: .15
BAROMETRIC PRESSURE: 30.22

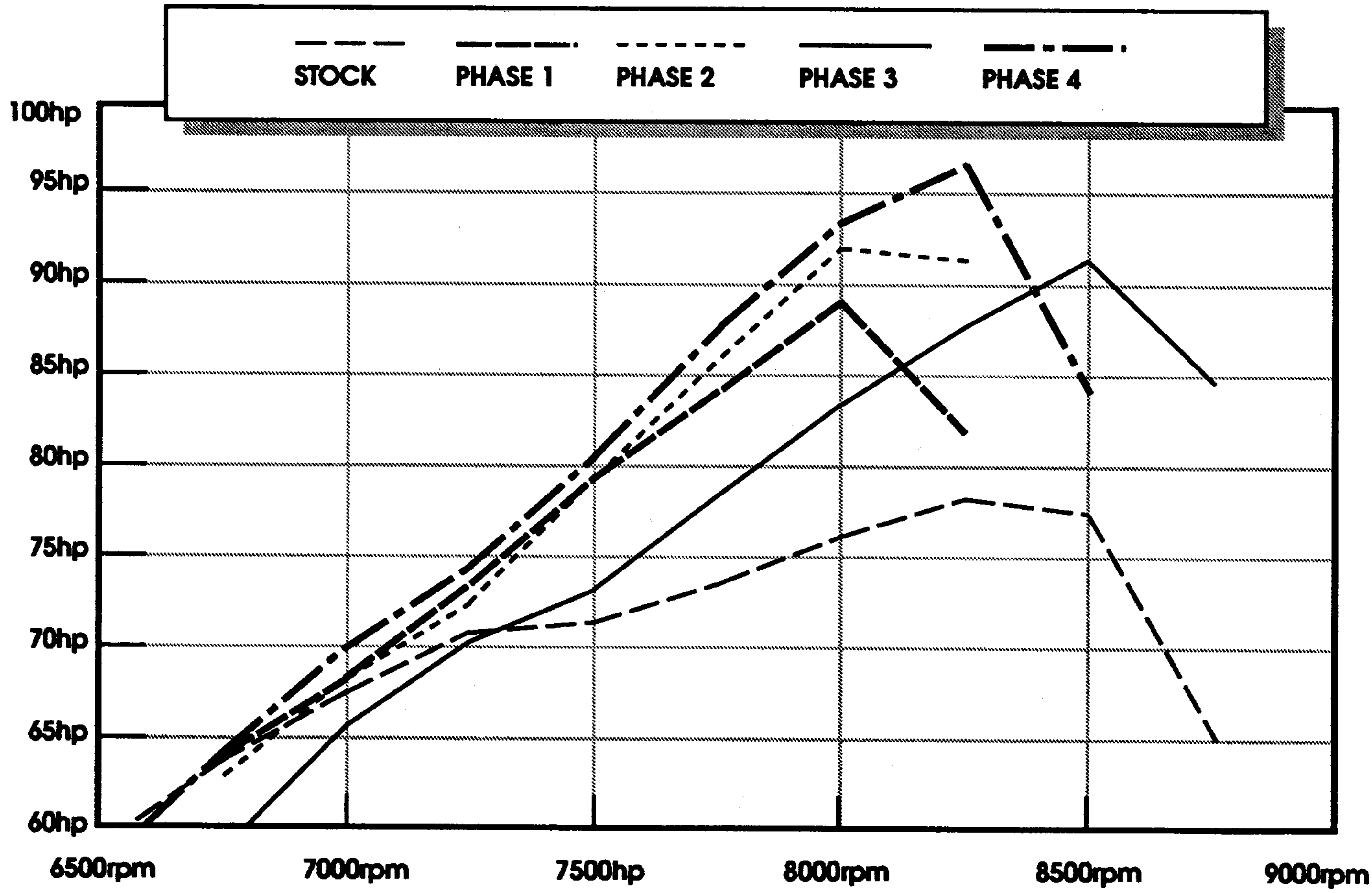
RPM	CBT	CBHP	FUEL	BSFC	CAT
6750	45.5	58.5	43.4	.72	35
7000	49.2	65.6	45.5	.67	35
7250	50.9	70.3	48.7	.67	35
7500	51.5	73.5	50.0	.66	34
7750	53.2	78.5	53.3	.66	36
8000	55.0	83.8	53.7	.62	35
8250	56.1	88.1	52.9	.58	35
8500	56.6	91.6	59.8	.63	36
8750	51.0	85.0	59.0	.67	37

PHASE 4. Removing the stock 40mm carbs and replacing them with 44mm carbs was next on our agenda. We eventually achieved good results by installing 360 main jets **(100 octane fuel)** and returning to the stock exhaust.

PHASE 4 DATA
ARCTIC MOD PORT SPECS
44MM CARBS, 360MJ, STOCK EXHAUST
Data for 29.92 inches Hg, 60 F dry air.
TEST: 100 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .700
VAPOR PRESSURE: .15
BAROMETRIC PRESSURE: 30.21

RPM	CBT	CBHP	FUEL	BSFC	CAT
6500	46.6	57.7	38.1	.64	40
6750	50.0	64.3	40.2	.61	39
7000	52.5	70.0	43.9	.61	39
7250	53.9	74.4	47.0	.61	38
7500	56.2	80.5	50.0	.60	38
7750	59.6	87.9	52.5	.58	38
8000	61.6	93.8	54.3	.56	40
8250	61.7	96.9	57.2	.57	40

Finally, reverting back to the mod cut pipes with the big carbs gave us 98.1 CBHP at 8500 RPM, **with an extremely low BSFC of .51**. Raising the jet size to 380 brought the BSFC up into the high fifties again, but the CBHP was lower than what we got with the stock pipes.



SWAINTECH

THERMAL BARRIER COATING

PRODUCT EVALUATION

Swain Technology, Inc. is a company in nearby Scottsville, N.Y. (716-889-2786) that specializes in industrial metal coatings--one of which is an electric plasma sprayed ceramic and metal combination they call "TBC", or Thermal Barrier Coating. One application for TBC has been on engine components, where the reduction of heat transfer is desired.

Dan Swain approached me in March of 1988 (pre **DYNOTECH**) to see if I was interested in making an impartial dyno evaluation of the TBC when applied to snowmobile engine components. At first, I was somewhat skeptical about trying ceramic coatings on my own engines.

Eight years ago, I had a bad experience with ceramic coating on the combustion chambers and pistons of my turbocharged 1075 cc Kawasaki motorcycle. In the quest for additional reliable horsepower, I had a thick .010+" coating of ceramic material applied to the piston domes and combustion chambers. My quarter mile speeds increased from 145 to 150 mph, but the fun was short lived. Slowly but surely, the ceramic coating started flaking off and my ring seal was destroyed by the highly abrasive material.

Dan assured me that the current technology that they use in applying this new material eliminates the problems that I had encountered in the past. The new coating is a mere .002" thick, and is metallurgically bonded to the aluminum, enabling it to match the thermal expansion of the base metal. If, in fact, the material would perform as Dan claimed, it would be worth trying on our modified Phazer "dyno mule".

The Yamaha Phazer engine employs a barely adequate fan to cool itself. At its rated mid-fifties horsepower, the fan does a fair job of cooling the engine. But, when the engine is perked up to 80 horsepower and beyond (as is easy to accomplish with a cold air kit, pipe, pistons, compression and porting) heat buildup is a definite problem. This heat buildup costs us horsepower and encourages detonation.

The logical way to reduce the Phazer's detonation would be to reduce the compression ratio, and/or fatten the jetting in the midrange and top end. Both of these, of course, reduce horsepower and fuel mileage.

We experimented with the idea of driving the fan faster; installing a shorter belt in conjunction with a smaller fan pulley might help alleviate the Phazer cooling problem.

With the Phazer on the dyno we tested such a setup. We installed our large air flowmeter on the fan air intake. The stock pulley arrangement yielded about 800 CFM at 7500 RPM. Installing the shorter belt and smaller fan pulley brought our fan airflow to about 1000 CFM at the same speed. This would surely help cure our cooling problem--but then we noticed that the Phazer had lost approximately four horsepower as a result of driving the fan so fast!

Accordingly, Dan Swain's TBC seemed like a logical thing to try on the Phazer. Applying it to the combustion chambers should reduce the amount of heat conducted into the heads during combustion, and then hopefully reduce the temperature of the intake charge on the next power stroke. Coating the pistons next should have a similar, and perhaps more dramatic effect on intake charge temperature; if the undersides of the pistons trans-

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ferred less heat to the intake charge, detonation might be further reduced.

I had Swaintech coat my combustion chambers and gasket sealing surfaces (to minimize the reduction of combustion chamber volume) with TBC. At the same time, they coated the fins with a black heat emitting material that Dan said they used on machine gun barrels for the U.S. Government.

To physically test the effectiveness of the TBC, we heated the dome of a stock piston with a small Mapp gas/air torch (3500 degrees F) for 30 seconds, and measured the piston diameter. The stock piston had grown .006". Then, a TBC coated piston was heated in an identical fashion, and the piston grew only .0035".

Next, we applied a small oxy-acetylene flame (6000 degrees F) to the dome of the stock piston, and melted a hole in it in 50 seconds. Moving the torch to the dome of the TBC coated piston, it took 85 seconds to get the aluminum hot enough to droop.

For our dyno evaluation of the TBC, we ran our Phazer in predetermined steps, from stone cold to totally heat soaked, while monitoring the outlet air temperature of the engine cooling fan shroud.

With the stock pistons and combustion chambers, we ran five 12 second acceleration tests from 5500 to 8000 RPM, with various measured "rest" periods between runs. CBHP varied from 83.1 cold to 80.7 totally heat soaked.

After replacing the stock heads with a set of combustion chambers coated with TBC, we waited several hours to completely cool the engine. We repeated the timed series of tests, and found that while our "cold shot" CBHP was virtually unchanged at 83.2, the heat soaked engine had one more (81.6) horsepower at peak, and several more in the midrange. Also, while the fan shroud outlet temperature curve was similar on the cold engines, the identically heat soaked TBC combustion chambers transferred much less heat into the heads.

Next, we replaced the stock pistons with a TBC coated set. Unfortunately, it was discovered that one of the stock pistons we had been testing with was minus part of a ring land (obviously the victim of some prior detonation). While our CBHP was improved slightly by the new TBC pistons, this glitch nullified the piston portion of our dyno evaluation.

A week later, I performed the same dyno evaluation after having SwainTech TBC coat the pistons and combustion chambers of our modified Polaris 650 engine. In this case, there was no change in either the CBHP of the engine or the temperature rise of the water.

Since installing the TBC coated pistons and combustion chambers, we have put about 500 miles on both the Phazer and our Polaris 650 powered Exciter, about half trail riding and half lake and field racing. The coating has been durable so far, with no apparent signs of flaking or erosion.

Because of the coating, we are able to run our Phazer ping-free on leaner jetting than we could before. And, when we occasionally detonate the engine, there is a reduced possibility of engine damage.

At the rate we ride around here, it will be at least another year before the question of the TBC's long term durability will be answered. For now, I'm quite content with the performance improvement of the Phazer. It runs detonation free on 92 octane fuel with jetting that used to require 100 octane.

I've always run the Polaris engine on at least 100 octane fuel (the heads are cut .050") with a BSFC in the mid to low .50's. It would be in-

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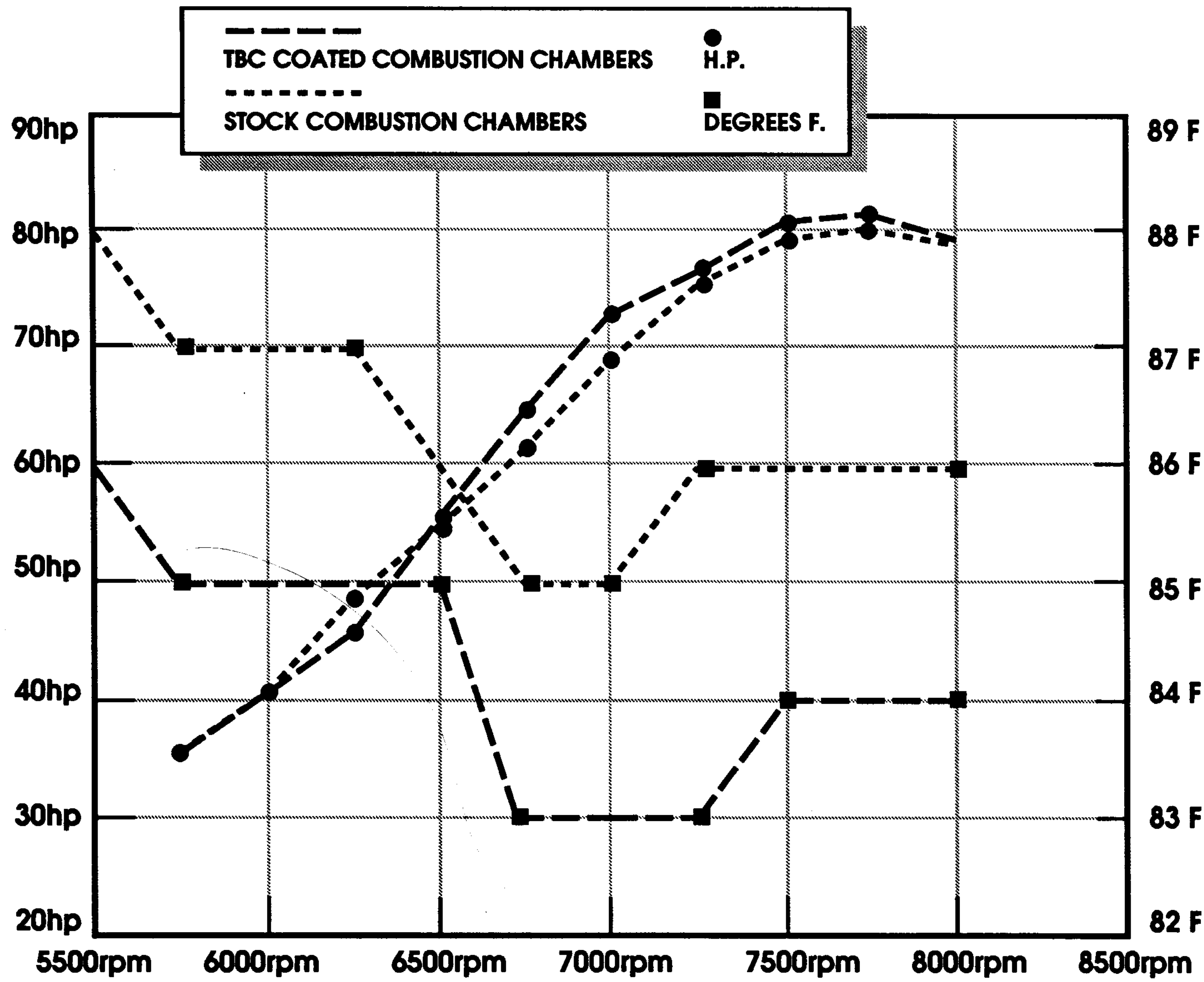
teresting to see if the engine would now survive a serious lake blast on 92 octane fuel. And, should I encounter silent-but-deadly detonation, will the TBC coated pistons give me a few precious seconds, as the horsepower drops, to lift the throttle before engine damage occurs? Perhaps we'll find out this winter.

UPDATE: **Just as the sixth issue was going to press, we encountered our first problem with some pistons coated with TBC.**

We were doing a dyno evaluation of a radically ported Phazer, with brand new TBC pistons, and found some of the coating on the transfer sides of the piston domes was flaking off after only 8 minutes of engine run time under load (30 tests).

We removed the pistons, and are returning them to SwainTech for analysis and retreatment. We'll keep you apprised of the situation as more information becomes available.



FEEDBACK JIM CZEKALA

THE 1990's
At press time, we had completed testing on the 1990 Mach 1 and 1990 Polaris 650--both are scheduled for publication in our 7th issue. The Mach has been blessed with a new rotary valve, more compression, additional port timing (by virtue of much thicker base gaskets), and a freer breathing airbox.

The Polaris 650 triple remains unchanged, with the exceptions of a newly designed higher performance three-into-one exhaust, and a new airbox.

Anyone who has resubscribed for the coming season and can't wait for these published dyno evaluations, may call 716-344-1313 and be provided with the basic test results.

"UPDATE PORTED" EXCITER UPDATE
In addition to the new harmonic balancer, PSI is recommending that ***anyone with the later version of the PSI twin pipes shorten the mag side header pipe 3/4".*** Richard Hiley added a balancer to his engine and shortened his mag header pipe. This allowed the engine to run, for the first time, in the mid 7000 rpm range on his track dyno.

ELECTRONIC FUEL INJECTION
One of the engineers at SuperFlow recently told me about one of their customers doing extensive dyno testing of electronic fuel injection (EFI) on snowmobile engines.

The company, Fuel Injection Research Specialties (address withheld at their request), has designed an EFI system compatible with snowmobile two-stroke engines. They are also **DYNO*TECH*** subscribers, and use our data to double-check their own dyno results on their carbureted test engines.

Whose engines are they applying the EFI to? One engineer that I have spoken to was understandably tight-lipped about specific applications, but I believe Arctco and Polaris are directly involved. He did tell me that the system has been field tested successfully for at least one winter.

In the Fall issue of Race & Rally magazine there is an article on Arctic Cat's fuel injection development. Accompanying the article is a photograph of a fuel injected Arctic Cat engine being tested on Arctco's dyno.

Rumors persist of a limited production run of EFI Indy 650's this winter. One interesting fact is that, for the first time this year, fuel injection will be ***legal in Formula III oval racing.*** We're not sure who requested that particular rule change, but it definitely wasn't Yamaha.

Kevin Cameron's TCD column in this issue deals with some interesting comparisons between carburetion and EFI.

SUBSCRIBER SURVEYS
I'd like to thank our subscribers who are taking the time to fill out and return the reader survey with their subscription renewals. I enjoy reading all of the personal comments and suggestions that some of you have included, and will take them into consideration.

Meanwhile, our staff has been busy compiling the results which will be included in a later issue, when all of the returns are in.

ISSUE #6--FINALLY!!!
We've talked to hundreds of people who are just now subscribing to DYNOTECH, and are requesting last season's issues. Even though most new subscribers knew of us last year, they wanted to "wait it out" to see if we might fold up after one or two issues. Well, here we are, one year and six issues later, and we're still testing, tuning, thrashing and typing. This has turned out to be a ton of work, but it sure is fun.

A lot of you who don't know me are wondering "who is this guy with the hard-to-pronounce last name? "si-kal-a". Prior to building my dynamometer testing facility, I was the typical frustrated snowmobile performance enthusiast. I've spent more of my wife's money than I care to admit on new snowmobiles that didn't perform as magazines and ads said they would, and on aftermarket parts and modifications that sometimes only increased the balance past due on her MasterCard.

I spent most of my winter weekends on the lakes, with translucent oil soaked shoe-boxes full of carb components, pistons, and clutch weights and springs, vainly searching for mythical powerpeaks that I felt may have existed only in the minds of my well-meaning mentors.

Was my clutching screwing up my horsepower? Was my horsepower screwing up my clutching? An

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engine dynamometer could tell me for sure.
Owning a welding supply and compressed gas business with several stores, 5000 accounts, and a group of very dedicated employees has provided me with the time and means to design, build, and operate the dyno testing facility. I needed one for my own sleds and motorcycles; if enough people would pay to use it, it could become a viable business entity.

As expected, there are lots of snowmobile enthusiasts willing to invest money in dyno tuning time to improve their performance. During the winter months, the dyno has been running nonstop testing and tuning snowmobiles and snowmobile engines for enthusiasts from all over North America.

What was surprising, however, was the demand by snowmobilers for the information that we were getting from the dynamometer. People who read automotive, boating, and motorcycle publications (e.g. Car and Driver/CYCLE) are used to seeing true horsepower numbers and performance data. Dyno test results, quarter mile times, true top speeds, and honest performance tests are expected and received.

Unfortunately, snowmobilers represent the only motorsport group that has been deprived of honest product evaluations.

Publishers of snowmobile literature evidently feel they need to be cozy with their advertisers. The amount that they charge readers for their issues (sometimes free) is a pittance compared to their advertising revenues. Perish the thought that some manufacturer, in a huff over a less than glowing product review, might pull their expensive multi-color ads!

I personally can't remember the last time I read a critical test in any major snowmobile publication. Could it be that all snowmobiles are created so wonderfully equal? "Technical" articles that you occasionally find in these publications, such as aftermarket pipe evaluations are often glorified advertisements authored by the people who make or sell the products.

Have we received any flack over the information we print? We never expected to produce a publication like this without hearing the occasional "rattling sabre". All of the snowmobile manufacturers and most of the aftermarket companies subscribe to DYNOTECH, and certainly not everyone is pleased with what we are doing.

We would hope that, instead of spending their time trying to badger or discredit us, companies would keep working on the development of their engines and components.

Today, **DYNO*TECH*** is your only source for "real world" information. Our subscribers are continually requesting that we evaluate clutching and suspensions, and do field performance tests. This represents an unsatisfied demand for information that our small publication cannot properly address.

Perhaps in the future, as word about **DYNO*TECH*** spreads and our subscriber base grows, this sort of subjective testing may become a possibility. For now, we will concentrate on objectively evaluating engine performance. We'll continue testing, thrashing, tuning and typing as long as you want us to. Like I said, this is fun.

CARL McQUILLEN (consulting editor issue #4)
At the latest Super Chevy Sunday street tire shootout at Norwalk, Ohio this summer, Carl's NOS 454 powered street legal (licensed, inspected, DOT legal treaded tires) Olds Cutlass lowered the record to 9.31 @ 153mph.

MODIFIED PHAZER PIPE SHOOTOUT
Because of the demand by our Mach 1 subscribers for the stock 1989 engine tested with aftermarket pipes, our Modified Phazer Pipe Shootout will be included in a later issue.

MORE BSFC...or was that WSFC?
Henry Beida, owner of Beida's Leisure (Bombardier dealer) in Fenwick, Ontario, Canada recently established a new Guiness Record on his Mach 1 with a non-stop 100 mile water skip on the Welland Canal. Henry's Mach was set up by Gary "Dr." Potyok, who used his Dyno generated BSFC numbers to determine the amount of gasoline required to complete the 100 miles at close to WOT on water without refueling.

Despite an auxiliary fuel tank, Gary figured it a tad too close. Just after completing the record 100 mile skip, Henry's Mach 1, heading toward a shore lined with a throng of exuberant spectators, ran out of gas and sank to the bottom of the canal in 20 ft of water. Henry owns the record, nonetheless.

INDY 500 PIPE SHOOTOUT
Derek has been bugging me every week to get on with this one. The sled is ready, but we are waiting for a few more pipes to become available.

SLP 400/440 INDY (Issue #5)
Our Carb Air Temperature readings were incorrectly listed. They were 31 to 32 degrees F throughout the test.

FUEL SYSTEMS PROBLEMS & POSSIBILITIES

THE CELLAR DWELLER KEVIN CAMERON

Carburetion is a familiar technology, but it has serious limitations. Carburetion is based upon the fact that moving air has less pressure than still air. The pressure difference between the carburetor throat and atmosphere is the "pump" that pushes fuel into the moving air stream. A variety of schemes are used to keep the fuel delivery in proportion to the air delivery.

When a two-stroke engine is "on the pipe", very strong wave action is pumping air in and exhaust out. It's relatively easy to get good carburetion in the powerband. It's harder below and above the band. Below the RPM of strong wave action, the intake pulse reaching the carburetors is weak (especially so in rotary-valve and large area reed engines), and the less violent the intake pulse, the weaker the mixture becomes. There is really no help for this problem, so it defines the bottom of useful power. If your engine won't carburate below X RPM, it won't run there.

As the engine revs past the pipe's RPM band, the pipe's reflected pressure wave begins to arrive too late to supercharge the cylinder with mixture than has been sucked into the header, and so the engine loses power, the pipe receives less energy, and the suction signal and the mixture weaken. This kind of operation, called over rev, can be necessary to broaden the range between minimum and maximum sled speed. A powerjet system is sometimes used to enrich top-end operation enough to drown this lean-out, but it's crude. Most powerjets just enrich top end so much that peak revs are lost.

Even on the pipe there are problems in matching fuel flow to airflow. As pipe comes into resonance, wave action in the intake system increases in violence, causing a tendency to enrichment. This is compensated for by an airbleed into the main system, or by a primary venturi which weakens the vacuum on the main system as airflow increases. Neither of these systems is as precise as we would like. Close examination of mixture on an instrumented dyno always shows mixture inaccuracies in some part of the engine's range. Very commonly, if the engine is jetted for best power on top, it will be lean at the bottom. To keep the engine from detonating on this lean mixture, tuners may have to put up with being a size or two rich on top.

The power of a two-stroke engine depends upon how much air can be blown through the cylinder to sweep out exhaust residue. With carburetors, it is mixture that's used as a "broom" in this way--not pure air--and much of it is lost out the exhaust in the scavenging process. In the most powerful racing engines, airflow exceeds displacement by more than two-to-one! This means that less than half the fuel is actually burned. The rest short-circuits out the pipe during scavenging--the price of achieving high charge purity and so, high power.

For a number of years, experimental engines have been tested in which fuel is injected late in the scavenging event, when there is no time for the injected fuel to reach the exhaust port. Such engines usually inject either into the transfer ports or through the rear cylinder wall. The problem with this is that with so little time for mixing with the air and for evaporation, mixture formation is poor. These types of injection we may call cylinder injection. With a carburetor, spraying its fuel into the intake air stream, the raw mixture enters the crankcase in wild turbulence, is heated and held there for a time, is accelerated up through the transfers, and swirls violently into the cylinder. During all this process, fuel mixing has plenty of opportunity to be completed.

Despite the difficulty of making two-stroke cylinder fuel injection work, when it has worked on test engines, the result has been nearly the same power as with carburetors, but with much lower fuel consumption. This, in a world where the EPA's axe is always ready to fall, is a very desirable achievement. The slight power loss comes from the loss of the fuel's cooling effect. Air refrigerated by evaporating fuel becomes more dense, and so you can get more of it in a given volume. Crankcase injection doesn't suffer this power loss.

There is also the question of fuel spray break-up. Especially with rotary-valve induction, if you look into the carburetor as an idling engine is accelerated under load into its powerband, you will at first see an irregular stream of blobs and beads of fuel dumping from the needle-jet. As the engine nears its power range and the pipe comes in, this pat-

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tem abruptly switches to two lobes of fine, white spray. What makes the difference? The energy in the intake stream is at first not enough to break up the fuel drops, but once the pipe begins to make the whole engine "ring", intake flow energy increases sharply and knocks the fuel into fog. With injection, some of the energy for fuel break-up comes from the fuel injection pump, and mixture formation is not so dependent on airflow violence. The large droplets that spray from a carb jet at low speed don't fully evaporate by the time they reach the chamber, and so the mixture must be enriched to make it burn properly. This, too, makes the engine fuel thirsty and sluggish in throttle response.

Now we must talk about yet another problem with the carburetors; fuel is added to the air stream no matter which way it moves. On a piston-port engine with long intake timing, there is always reverse flow when running below the power band (for instance, when the engine is accelerated from idle in response to sudden throttle opening). You see the reversion as a fog of fuel at the carb bells. Here is the problem; the air picks up fuel on its way into the engine, picks it up again as it is blown back through the carb, then waits in the airbox to be taken in and carburated a third time. This makes the very bottom RPM range tend to be extremely rich.

With cylinder injection, this is no longer a problem, for only air is admitted to the crankcase. With crankcase fuel injection, multiple carburetion is still impossible, because fuel is added to the air stream only when the control system orders it. In either case, the low speed mixture does not enrich from multiple carburetion, and so the mixture remains easily ignitable.

For these reasons, snap throttle response from the bottom is potentially vastly improved by injection.

Snowmobiles operate over a very wide temperature range. Carburetion that is rich enough for full-power running at -40 degrees is going to be hideously rich at +32 degrees. Sleds are also frequently used at higher altitudes. Experienced users reject, but laymen on trail sleds must endure compromised carb settings that sacrifice power and fuel consumption most of the time--just to be safe when it is very cold. Carburetion enriches with increasing altitude, a falling barometer, or rising temperature--and vice versa. A fuel injection system that measures air density can compensate for these weather and altitude changes, keeping performance much closer to optimum all the time, rather than being correct only at one temperature and pressure, and wrong the rest of the time.

Injection systems now in use on cars and motorcycles offer great advantages in cold starting and warmup because they don't depend upon crude chokes. Instead, they proportion fuel according to measured need.

There are problems caused by the bulk and special needs of carburetors. Carbs don't always fit as close to the engine as we'd like (the shortest possible intake length seems to work best, and it's usually shorter than the shortest carb, set as close as you can get it) and they don't like to be tipped more than 15-20 degrees from horizontal. With injection, the intakes can be any length, located anywhere, at any angle. In two-stroke engines the injectors may not even be in the throttle body, but rather on the cylinder it self somewhere--likely on the side opposite the exhaust. Engines designed from the start for injection can use novel architectures--such as with horizontal cylinders with vertical intakes.

The fuel in a racing snowmobile's fuel bowl stands at a 45 or 50 degree angle during cornering, and this often causes problems with either fuel starvation or flooding. Operation on rough terrain also disturbs carburetion. All sorts of tricky baffles and jet shrouds may have to be tried to solve these problems. With injection, there are no fuel bowls, and the system doesn't care at what angle it operates.

There are two basic types of injection--open loop, and closed loop. Current production automobiles use closed loop control. In such systems, an oxygen sensor in the exhaust continuously informs a control computer as to whether the mixture is rich or lean, and the fuel delivery is adjusted to suit. The mixture strength continuously and rapidly cycles from rich to lean and back over a very narrow range that keeps combustion centered on a chemically correct mixture (no oxygen or fuel left over after burning). This kind of control is practical only in engines which flow very little extra air besides what they actually trap in their combustion chambers. In a racing four-stroke engine, long valve overlap sends lots of unreacted oxygen and fuel into the exhaust pipe. This is even more true of two-strokes. Such engines therefore must use open-loop control. It works as follows.

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A test engine is set up on the dyno and instrumented so its torque, airflow, and other operating variables can be measured. The best fuel flow for every possible combination of RPM, throttle setting, rate of acceleration, engine temperature, etc., is then found by actual test, and is recorded in a complex table called a map.

This map is encoded on a device called an EPROM (electronically programmed read-only memory), connected to the engine's control computer. In operation, the computer reads engine variables from sensors (airflow meter, throttle angle encoder, air and engine temperature probes, etc.) then looks up the correspondingly correct amount of fuel to inject, and the proper injection timing. Such a system depends absolutely on everything on a given engine being the same as it was on the dyno test engine on which the map was developed. On production engines this is just fine, but if you modify your engine, you'll also have to reprogram the fuel control.

Racers using such open loop systems must learn computer skills. The EPROM containing the fuel control map cannot be altered, so a new one must be encoded, or "burned", with new information. This involves repeating the dyno tests described above, but with the modified engine. In some cases, alternative EPROMs ("chips") are made available. You have seen them advertised for performance cars.

Fuel injection is coming into use in motorcycle racing, creating a new problem. Manufacturers use such systems to control not only fuel delivery, but also who wins and loses in racing. If you have been in their terms, "good", you are rewarded with the hot chips. If you have been "bad", you run stock. Stubborn, intelligent, and determined as racers are, some are learning about computers, cracking the fuel injection control codes, and writing their own software, but this isn't practical for everyone. In some cases, trusted individuals are given the complete package--computer code information, EPROM burner, computer interface hardware, and training in their use.

Why must computers be involved at all? Only a computer is fast and accurate enough to deal with the many variables and rapid changes involved in a running two-stroke engine.

A desirable future for fuel injection is one in which the tuner can download his fuel-control mapped to a lap top computer, alter to suit conditions, then reload it into the control computer in the vehicle. This is already the situation in some kinds of auto racing.

There is the possibility that the EPA will figure in all of this, mandating that fuel control codes be protected by encryption to prevent "improper persons" from altering mixture and so spewing illegal levels of pollutants into the atmosphere.

There are, fortunately, new technologies for measuring what is happening in the combustion chamber. With these it may be possible at some future time to create closed loop fuel injection systems that can compensate for almost any change--whether it be in the weather, in the engine's state of tune, or in the wear of engine parts. For the moment, open-loop systems can accomplish wonderful gains over carburetors, especially in stock engines.

I spoke recently with Ron Chastain of Fuel Injection Research Specialties. This company, after six years of development and testing, is close to production of an open loop crankcase injection system for production snowmobiles, to be released in small quantities this season. He wasn't able to reveal intimate details of the system, but it is weather and altitude compensating and reportedly offers wider engine power range, tremendously improved throttle response as well as substantial reduction in fuel consumption. We will bring you more information on this new system in our next issue.

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