Volume 2 Number 1 1989

DYNOTECH

THE SNOWMOBILE PERFORMANCE PUBLICATION

WELCOME

NEW SUBSCRIBERS AND RESUBSCRIBERS

DYNO*TECH*, the snowmobile performance publication, is based upon data generated at the C&H Dyno Service public dynamometer testing facility in Batavia, N.Y.

Representing an investment of well over $100,000, C&H Dyno Service utilizes a fully instrumented and computerized SuperFlow SF-901C. The SuperFlow dyno in conjunction with a revolutionary hydraulic chassis fixture, makes possible accurate, repeatable dyno tests without removing engines from the chassis. Typically, engines are left in the sleds, and the crankshafts are connected directly to the SuperFlow dyno via a custom torsionally dampened driveshaft system. Air from outside our testing facility is ducted and blown over the sleds at 80 mph, just as though the sled were being driven in the field. We use a roof mounted 7.5 H.P. industrial blower to accomplish this.

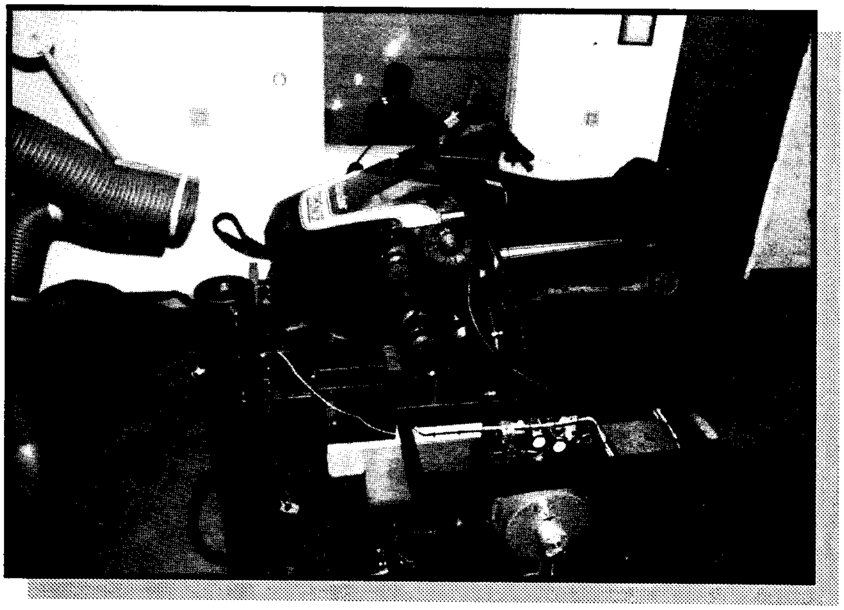
Computer control of the engine during testing allows us to perform what is called "transient" testing, or "acceleration tests". The SuperFlow computer continually monitors engine speed, torque, horsepower, fuel flow, air flow, air/fuel ratios, and **B**rake **S**pecific **F**uel **C**onsumption during our short duration tests. We can opt to have the computer log the engine data wherever we wish and generally elect to show the data every 250 RPM.

Typical (non-computerized) dyno testing requires that the engine be held "steady state" for a period of time allowing analog or digital gauges to stabilize, before being observed by the operator and manually logged with a pen or pencil. Every RPM level where data is needed requires a similar "step and hold" procedure.

Computer technology has enabled us to take this tortuous grunt-and-hold multi-step test and condense it accurately into a smooth ten or fifteen second acceleration test! Not only are the engines (and engine owners) happier with the new dyno testing technology, but the acceleration mode of testing models real-world carburetion and pipe problems as well. Regardless of how well a sled is "clutched", the engine still must muscle its way, every RPM, from clutch engagement to shift speed, just the way the SuperFlow dyno tests them. Anyone who criticizes this modern method of engine analysis most certainly lacks the sophisticated computerized equipment necessary to perform transient testing.

The test data normally provided in **DYNO*TECH*** is referred to as "standard corrected" data. That is, the torque and horsepower that the test engine would make at sea level (29.92 in. hg.), 60 degrees F. This is the most commonly used measure of snowmobile engine performance.

One of Bender Racing's 854cc "Avalanche" three cylinder Yamaha Exciters being dialed in on the C&H Dyno.



PIPE SHOOTOUT #8

STOCK 1989 POLARIS INDY 500

For our 8th Pipe Shootout Jim Pixley provided us with an engine from his stock 1989 Indy 500. The engine had 500 miles on it and, like the Mach I tested in issue #6, made more power than the brand new Indy 500 we tested in issue #2.

Pipe Shootouts are easier to manage with the engine removed from the chassis and mounted on our engine plate. This facilitates pipe and jet changes and allows us to leave the chassis stock (unfortunately, we therefore cannot comment on pipe fit).

We disconnected the injection oil supply line from the injection pump and used VP C-12 fuel premixed 32:1 with Polaris oil. Our objective throughout testing was to maintain the BSFC in the mid sixties for all of the pipes. *Please make note that the jetting spec listed for each pipe combination should be safe for 92 octane gas and 50 degrees Fahr. at sea level. Consult your Mikuni Pocket Tuner to correct the jetting for your conditions.*

The first test, used as a baseline, is with the stock pipe and factory air box. For the next test we retained the stock pipe but gutted the air box. **Be sure to compare the aftermarket pipes against this test as all of the aftermarket pipes were tested with the gutted air box.** In the third test, the PSI single pipe that we used is the pipe they are selling for the 1989 Indy 400. PSI's single 500 pipe wasn't available at test time, but will be included in a future test.

During testing we tried to record data at lower rpms than we have in the past. Certain engine/pipe combinations don't cooperate well with the dyno under low rpm/full throttle conditions, but wherever we were able to record consistent and repeatable data we have included it for comparison.

We should also note that Aaen Performance does not recommend their twin pipes for a stock motor. A modified Indy 500 pipe shootout, with a motor ported similar to Aaen's recommendations, will be included in a future issue.

Make & Model	1989 Polaris Indy 500
Engine Type	Piston Port Twin
Cooling	Liquid
Displacement	488cc
Bore & Stroke	72x60
Carburetion	VM38/2/Mikuni
Exhaust	Single with Canister

STOCK PIPE 270 MJ NO dB
Data for 29.92 inches Hg. 60 F dry air.

TEST: 100 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .700
VAPOR PRESSURE: .32
BAROMETRIC PRESSURE: 30.22

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
4742	15.9	14.4	14.3	45.6	14.6	.99	49
5022	20.6	19.7	16.7	55.5	15.3	.84	49
5336	23.5	23.9	17.1	56.3	15.1	.71	49
5698	32.8	35.6	32.6	82.6	11.6	.91	48
6000	40.0	45.7	33.5	97.1	13.3	.72	49
6250	43.6	51.9	36.4	106.7	13.5	.69	48
6500	47.4	58.7	42.5	113.6	12.3	.72	49
6750	50.3	64.6	46.9	120.1	11.8	.72	50
7000	51.3	68.4	48.5	124.4	11.8	.70	48
7250	51.7	71.4	48.1	126.9	12.1	.67	49
7500	50.3	71.8	48.3	129.9	12.3	.66	42
7750	48.7	71.9	48.4	129.0	12.2	.66	47
8000	41.5	63.2	48.3	128.1	12.2	.75	48

BASELINE STOCK PIPE GUTTED AIRBOX 270 MJ 86 dB
Data for 29.92 inches Hg. 60 F dry air.

TEST: 100 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .700
VAPOR PRESSURE: .32
BAROMETRIC PRESSURE: 30.23

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
4352	17.9	14.8	21.1	61.1	13.3	1.40	48
4970	19.6	18.5	18.0	57.4	14.6	.96	47
5152	30.2	29.6	28.8	83.1	13.2	.96	48
5500	33.6	35.2	25.5	82.3	14.8	.72	48
5750	37.7	41.3	31.9	100.3	14.4	.76	48
6000	40.9	46.7	32.8	110.2	15.4	.69	48
6250	44.7	53.2	34.0	116.6	15.7	.63	48
6500	48.3	59.8	36.3	122.5	15.5	.60	47
6750	50.3	64.6	42.2	128.1	13.9	.65	48
7000	52.6	70.1	44.9	132.0	13.5	.63	48
7250	52.3	72.2	46.0	134.0	13.4	.63	48
7500	51.3	73.3	46.4	135.2	13.4	.62	48
7750	49.7	73.3	46.9	135.2	13.2	.63	49
8000	46.2	70.4	45.5	134.5	13.6	.64	50

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PIPE SHOOTOUT

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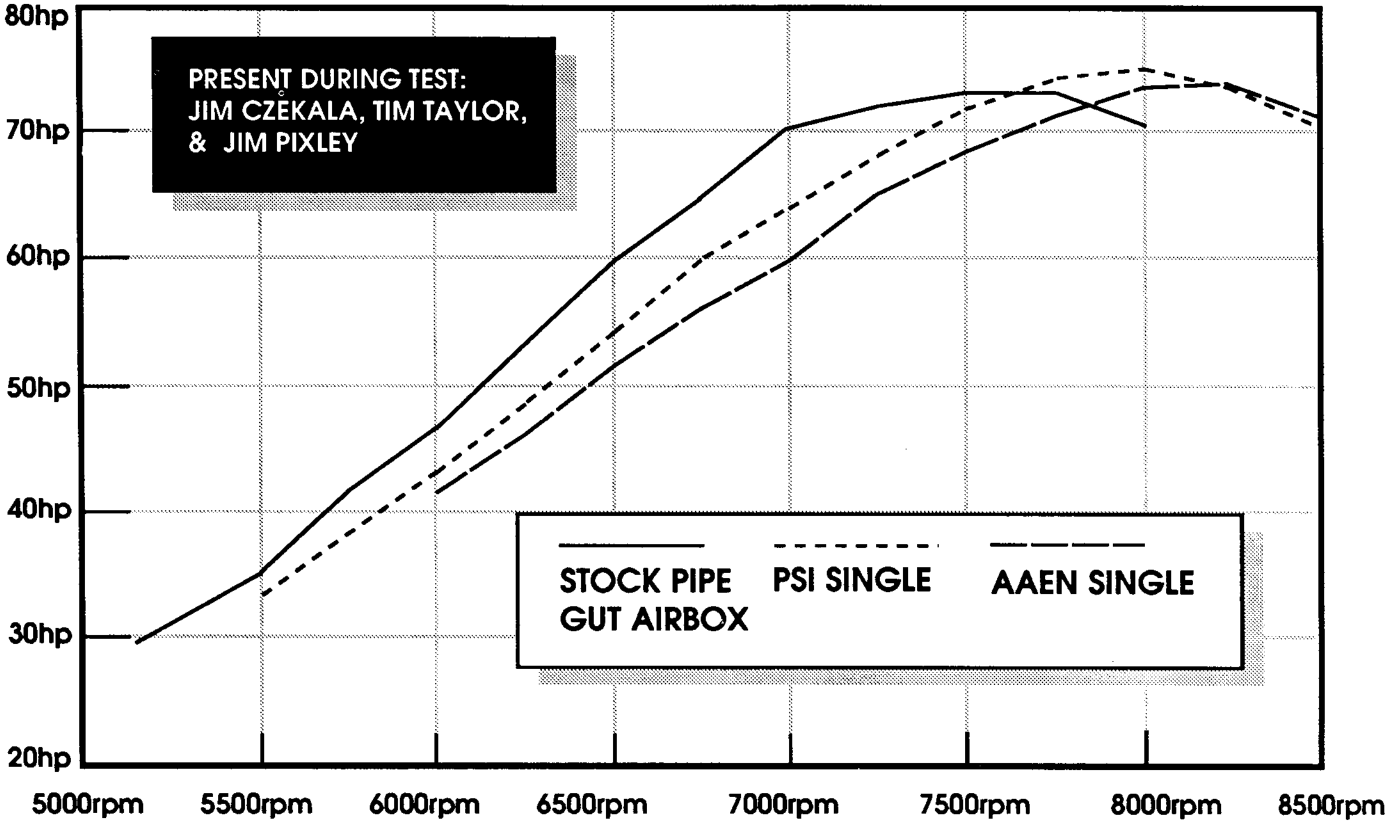
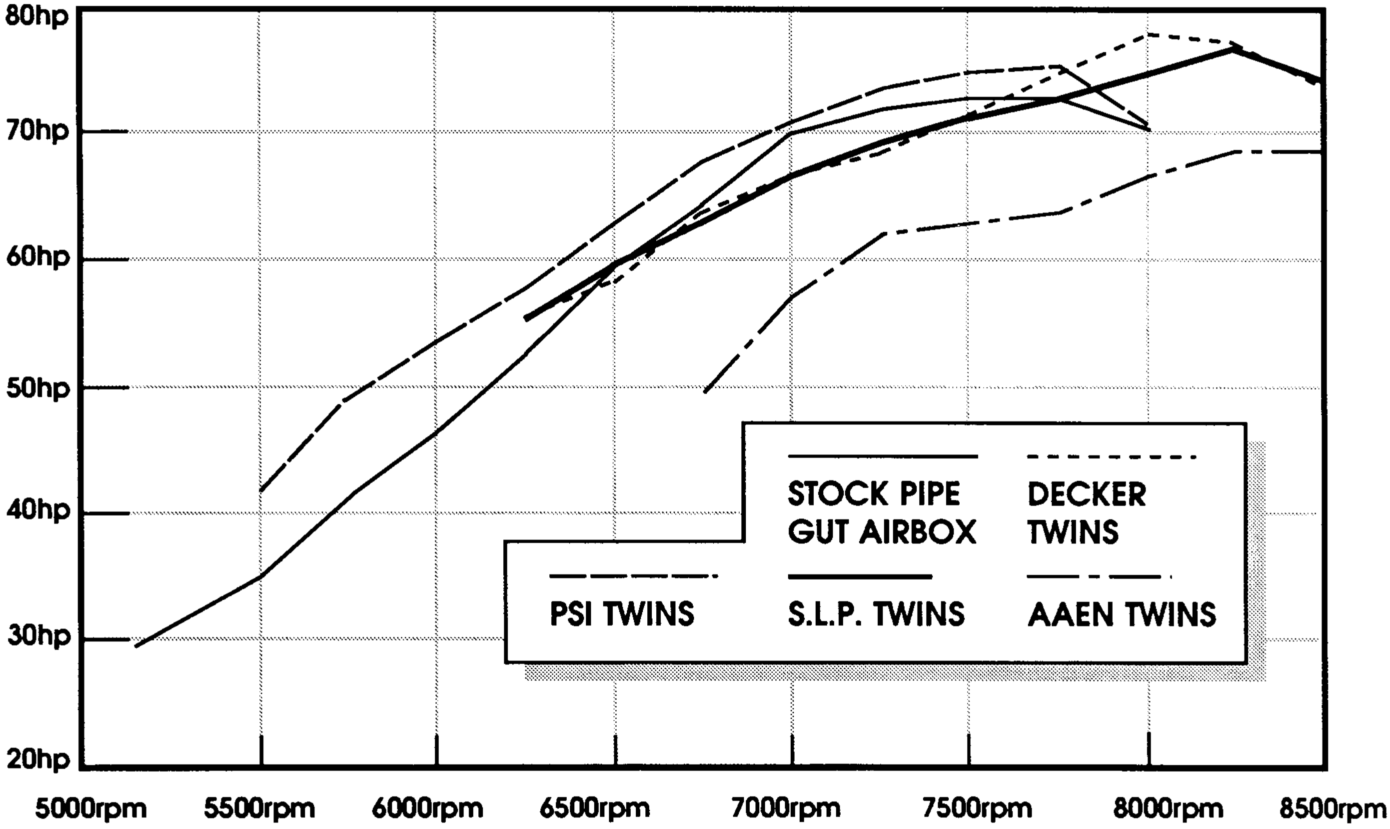


PRESENT DURING TEST:
JIM CZEKALA, TIM TAYLOR,
& JIM PIXLEY



PIPE SHOOTOUT

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PSI SINGLE PIPE

290 MJ NO dB

Data for 29.92 inches Hg. 60 F dry air.

TEST: 100 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .700
VAPOR PRESSURE: .32
BAROMETRIC PRESSURE: 30.24

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
3944	17.7	13.3	15.7	50.2	14.7	1.17	49
4440	17.4	14.7	18.5	56.2	13.9	1.24	50
5150	18.9	18.5	17.2	55.6	14.8	.92	49
5522	31.5	33.1	28.9	85.9	13.6	.86	47
5750	34.6	37.9	33.6	96.7	13.2	.88	48
6000	37.7	43.1	34.6	101.5	13.5	.79	48
6250	41.4	49.3	35.8	106.7	13.7	.72	48
6500	43.9	54.3	37.0	111.2	13.8	.67	48
6750	46.9	60.3	40.1	117.0	13.4	.66	48
7000	48.1	64.1	42.6	121.2	13.1	.66	49
7250	49.4	68.2	44.7	124.5	13.0	.64	48
7500	50.4	72.0	45.3	127.3	12.9	.62	47
7750	50.5	74.5	47.3	129.2	12.5	.63	48
8000	49.4	75.2	46.9	129.8	12.7	.62	48
8250	46.8	73.5	47.1	130.5	12.7	.63	48
8500	43.9	71.0	45.8	129.8	13.0	.64	48

AAEN SINGLE PIPE

290 MJ 88 dB

Data for 29.92 inches Hg. 60 F dry air.

TEST: 100 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .700
VAPOR PRESSURE: .32
BAROMETRIC PRESSURE: 30.28

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
3946	16.7	12.5	17.7	53.5	13.9	1.39	50
5750	28.0	30.7	26.9	78.8	13.5	.86	50
6000	36.3	41.5	33.1	98.4	13.7	.79	51
6250	38.7	46.1	34.3	104.3	14.0	.74	49
6500	41.7	51.6	35.5	109.6	14.2	.68	50
6750	43.7	56.2	39.4	113.3	13.2	.69	49
7000	44.9	59.8	42.1	117.0	12.8	.69	49
7250	47.0	64.9	42.7	120.7	13.0	.65	50
7500	48.0	68.5	43.1	124.3	13.2	.62	49
7750	48.5	71.6	43.9	126.6	13.2	.60	48
8000	48.3	73.6	44.4	127.9	13.2	.60	49
8250	47.1	74.0	44.0	129.0	13.5	.59	49
8500	44.5	72.0	45.6	129.6	13.1	.62	49

AAEN TWIN PIPES

290 MJ 92 dB

Data for 29.92 inches Hg. 60 F dry air.

TEST: 100 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .700
VAPOR PRESSURE: .32
BAROMETRIC PRESSURE: 30.26

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
6750	38.4	49.4	44.0	121.7	12.7	.88	51
7000	43.1	57.4	47.1	127.3	12.4	.81	50
7250	45.3	62.5	47.3	129.8	12.6	.75	49
7500	44.4	63.4	47.3	129.0	12.5	.74	49
7750	43.5	64.2	47.0	129.2	12.6	.72	49
8000	44.2	67.3	46.4	128.6	12.7	.68	50
8250	43.9	69.0	46.7	129.2	12.7	.67	49
8500	42.5	68.8	46.8	130.2	12.8	.67	50
8750	41.3	68.8	47.1	131.7	12.8	.68	51
9000	39.8	68.2	47.4	134.6	13.0	.69	49

DECKER TWIN PIPES

290 MJ 92 dB

Data for 29.92 inches Hg. 60 F dry air.

TEST: 100 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .700
VAPOR PRESSURE: .32
BAROMETRIC PRESSURE: 30.26

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
6250	47.1	56.1	41.5	123.2	13.6	.73	48
6500	47.6	58.9	45.2	129.8	13.2	.76	47
6750	49.8	64.0	48.3	134.9	12.8	.74	46
7000	50.4	67.2	48.4	135.7	12.9	.71	47
7250	50.0	69.0	50.2	134.9	12.3	.72	47
7500	50.3	71.8	49.6	135.5	12.5	.68	46
7750	51.0	75.3	48.7	135.5	12.8	.64	46
8000	51.3	78.1	48.5	138.5	13.1	.61	48
8250	49.3	77.4	48.0	142.4	13.6	.61	47
8500	45.7	74.0	50.2	144.1	13.2	.67	46
8750	33.9	56.5	49.6	140.5	13.0	.86	46

PSI TWIN PIPES

260 MJ 86 dB

Data for 29.92 inches Hg. 60 F dry air.

TEST: 100 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .700
VAPOR PRESSURE: .32
BAROMETRIC PRESSURE: 30.24

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
4342	20.4	16.9	20.5	57.9	13.0	1.20	49
5268	23.2	23.3	22.9	71.2	14.3	.97	49
5500	39.9	41.8	29.3	100.5	15.7	.69	49
5750	45.0	49.3	37.0	121.1	15.0	.74	49
6000	47.2	53.9	40.5	128.7	14.6	.74	49
6250	49.0	58.3	40.9	129.1	14.5	.69	50
6500	51.0	63.1	42.3	129.6	14.1	.66	49
6750	52.8	67.9	42.2	131.2	14.3	.62	50
7000	53.3	71.0	44.7	134.5	13.8	.62	49
7250	53.7	74.1	44.8	137.4	14.1	.60	49
7500	52.8	75.4	46.7	137.7	13.5	.61	49
7750	51.2	75.6	46.9	137.3	13.4	.61	50
8000	46.5	70.8	47.4	136.9	13.3	.66	50
8250	31.6	49.6	44.1	133.6	13.9	.88	49
8500	25.8	41.8	41.2	128.0	14.3	.97	48

SLP TWIN PIPES

280 MJ 94 dB

Data for 29.92 inches Hg. 60 F dry air.

TEST: 100 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .700
VAPOR PRESSURE: .32
BAROMETRIC PRESSURE: 30.27

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
5202	24.6	24.4	24.9	71.1	13.1	1.00	48
5422	26.5	27.4	27.9	75.9	12.5	1.00	48
5816	23.6	26.1	22.5	68.0	13.9	.85	48
6090	36.6	42.4	29.2	89.3	14.0	.68	48
6250	46.6	55.5	39.8	118.9	13.7	.71	49
6500	48.7	60.3	43.8	130.2	13.6	.72	49
6750	49.4	63.5	46.2	133.1	13.2	.72	49
7000	50.5	67.3	47.9	133.6	12.8	.70	49
7250	50.6	69.8	48.2	133.0	12.7	.68	49
7500	50.0	71.4	49.1	134.0	12.5	.68	49
7750	49.6	73.2	48.3	135.9	12.9	.65	50
8000	49.4	75.2	48.1	137.4	13.1	.63	50
8250	48.9	76.8	47.8	139.3	13.4	.61	50
8500	46.0	74.4	48.2	141.2	13.5	.64	49
8750	41.5	69.1	48.1	141.9	13.5	.69	49

STOCK '90 MACH I

This 1990 Mach 1 engine was the third one brought for analysis by Dan Jenkins of J&J Sales and Service in Huron, Ohio (the other two having been the 1989 Mach 1 that Bombardier "tuned up", and the 1989 Mach 1 stocker that we "tuned up" in issue #6). The 1990 engine was brand new, fresh out of the crate, and differs from the 1989 version in several ways:

1. The addition of two 1 3/4" holes in the top of the airbox necessitated increasing the main jet spec to 340-360 to provide a safe BSFC.

2. A more radical "209" rotary valve has altered the intake timing.

3. Increasing the base gasket thickness by .016" effectively increases the transfer and exhaust port timing.

4. Cutting .025" from the cylinder head restores the compression lost with the thicker base gaskets, and further reduces the squish to @ .050".

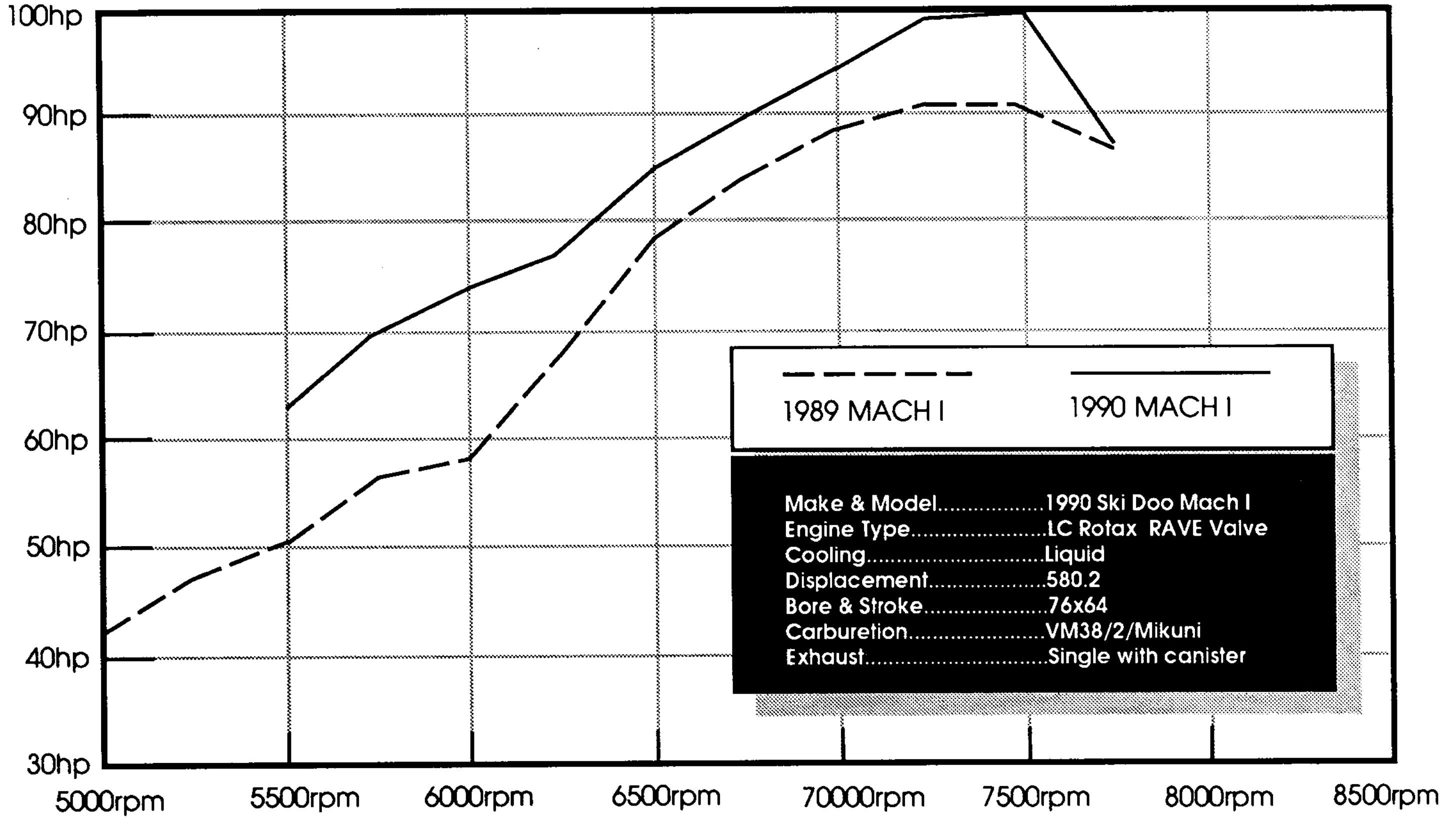
5. The outlet of the exhaust pipe has been increased to 33mm. This modification reduces engine backpressure. In addition, the RAVE springs in our 1990 engine were .125" longer than those in the two 1989 engines that we tested earlier. Apparently, the reduced backpressure in conjunction with what are possibly stiffer rave springs allow the RAVE valves to open later (more correctly than they did last year--see issue #2). Be this as it may, the graphic comparison reveals that the 1990 power curve is devoid of last year's early rave opening dip at 6000 RPM, giving our 1990 engine a ***16 horsepower advantage at that point.***

For this test, we corrected our main jets down to 290-310 to compensate for our 80 degree F. Carb Air Temperature. 100 LL av gas was used, and the oil injection was retained.

STOCK 1990 MACH I 290 310 MJ
Data for 29.92 inches Hg. 60 F dry air.

TEST: 100 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .700
VAPOR PRESSURE: .83
BAROMETRIC PRESSURE: 30.12

RPM	CBT	CBHP	FUEL	BSFC	CAT
5500	59.2	62.0	32.5	.55	80
5750	63.4	69.4	45.2	.68	81
6000	65.1	74.4	48.5	.68	81
6250	64.8	77.1	49.5	.67	82
6500	68.6	84.9	51.1	.63	81
6750	69.8	89.7	55.6	.65	81
7000	70.6	94.1	57.7	.64	80
7250	71.6	98.8	60.5	.64	80
7500	69.5	99.2	62.1	.66	81
7750	59.0	87.1	65.8	.79	80
8000	37.9	57.7	61.7	1.13	80



Make & Model	1990 Ski Doo Mach I
Engine Type	LC Rotax RAVE Valve
Cooling	Liquid
Displacement	580.2
Bore & Stroke	76x64
Carburetion	VM38/2/Mikuni
Exhaust	Single with canister

STOCK '90 INDY 650

Make & Model	1990 Polaris Indy 650
Engine Type	Liquid 3 Cylinder
Displacement	648cc
Bore & Stroke	67.72x60
Carburetion	Slide/3/Mikuni
Exhaust	3 into 1 with Canister

This 1990 Polaris 650 was brought to us for evaluation by Pete Webb of Webb's Polaris in Baldwin, N.Y., Polaris area rep Rick Baxter also helped out during the test session. Despite stories circulating last year concerning "improved" porting for the 1990 Polaris triple, the engine remains unchanged from the 1989 design. The "W" pipe also is unchanged. However, the single expansion pipe and canister have been redesigned (see photo). Also, an additional air intake hose has been added to the mag side of the airbox. We constructed a manifold to connect the two airbox openings to our single air flowmeter.

While the stock main jet size remains unchanged at 260, the midrange carb specs have been altered somewhat. Richer Q2 needle jets replace the P8's we have seen for so many years. The needle jets affect part throttle and mid range WOT (**W**ide **O**pen **T**hrottle) fuel flow.

Throughout testing we used the stock oil injection with C-12 gasoline. The stock Q2 needle jets were retained. Consulting our Mikuni pocket calculator, we corrected our main jets to 220 to compensate for the 70+ degree CAT (**C**arb **A**ir **T**emperature). After a break-in period, we did some initial testing with the 1989 pipes installed to establish a good baseline against which to compare the new pipe.

STOCK 1990 INDY 650 1989 PIPE 230 MJ

Data for 29.92 inches Hg. 60 F dry air.

TEST: 100 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .730
VAPOR PRESSURE: .58
BAROMETRIC PRESSURE: 30.29

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
7000	68.4	91.2	62.9	155.7	11.4	.70	69
7250	67.6	93.3	66.7	162.3	11.2	.73	68
7500	65.6	93.7	67.4	162.9	11.1	.73	69
7750	63.0	93.0	68.8	161.6	10.8	.75	69
8000	59.2	90.2	69.5	159.8	10.6	.79	69

Next, we installed the 1990 expansion chamber and canister. The initial result was that the engine was much easier to "drive" on the dyno. We had expected to trade off some midrange power for the increased peak power, at the higher RPM power peak, but this didn't occur. The new pipe developed more CBHP over a broader RPM range.

STOCK 1990 INDY 650 1990 PIPE 220 MJ Q2

Data for 29.92 inches Hg. 60 F dry air.

TEST: 100 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .730
VAPOR PRESSURE: .58
BAROMETRIC PRESSURE: 30.26

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
7000	67.8	90.4	63.5	151.6	11.0	.72	71
7250	69.4	95.8	64.4	163.0	11.6	.69	73
7500	68.9	98.4	65.0	163.8	11.6	.68	74
7750	66.9	98.7	66.5	163.9	11.3	.69	73
8000	64.1	97.6	69.3	163.1	10.8	.73	73
8250	60.1	94.4	68.5	162.1	10.9	.74	73
8500	55.1	89.2	69.9	161.5	10.6	.80	73

Because our BSFC was so safe, we reduced the fuel flow 5% by going to 210 main jets. *With the stock airbox and a CAT of 70 degrees F, this would be the leanest trail spec we would recommend on guaranteed 92 octane fuel.*

STOCK 1990 INDY 650 1990 PIPE 210 MJ Q2

Data for 29.92 Inches Hg. 60 F dry air.

TEST: 100 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .730
VAPOR PRESSURE: .58
BAROMETRIC PRESSURE: 30.271

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
7000	68.2	90.9	60.8	157.7	11.9	.68	72
7250	70.1	96.8	61.4	163.2	12.2	.65	73
7500	69.3	99.0	62.2	164.9	12.2	.64	70
7750	67.8	100.0	63.1	164.4	12.0	.64	71
8000	65.3	99.5	64.3	163.9	11.7	.66	71
8250	61.9	97.2	64.3	163.0	11.6	.68	71
8500	57.1	92.4	63.3	161.6	11.7	.70	71

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STOCK 1990 INDY 650

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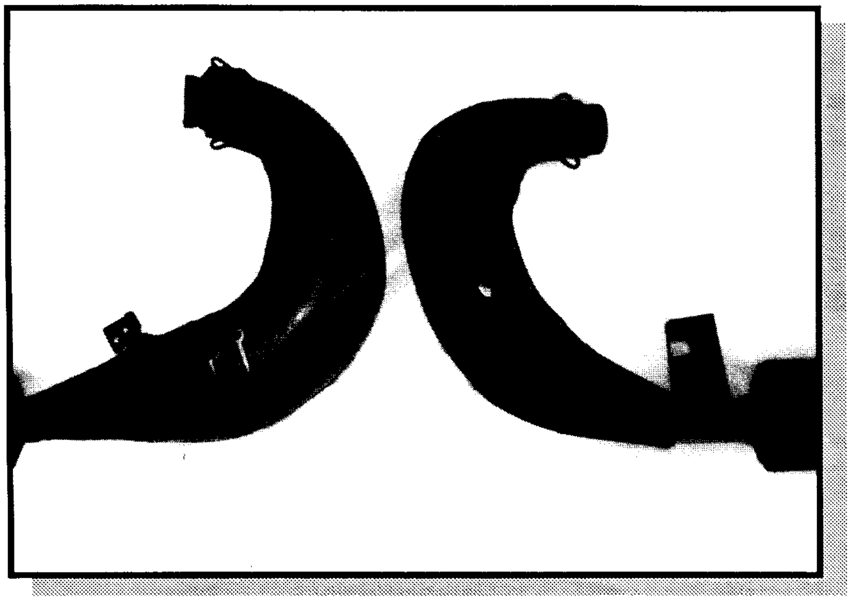
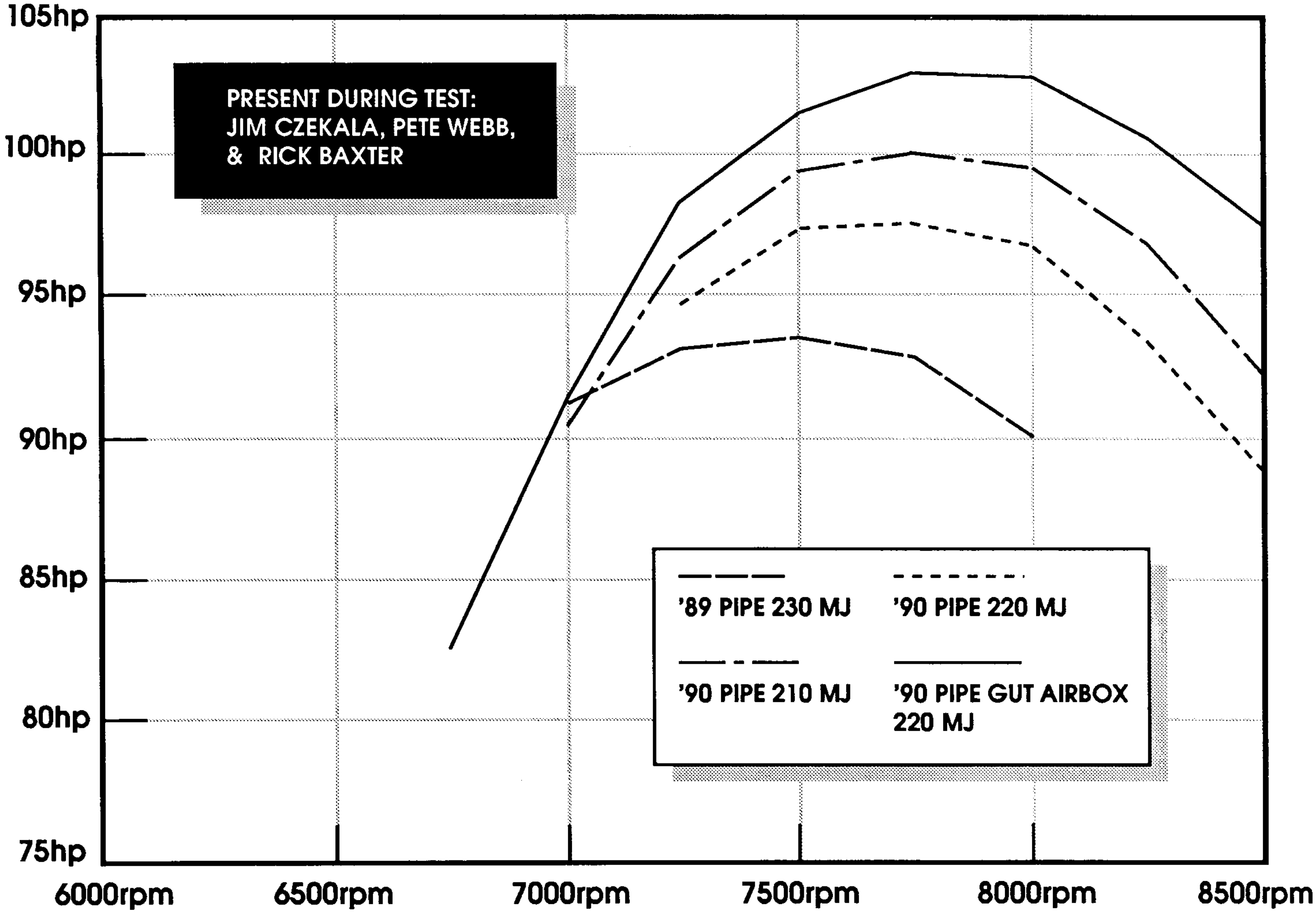


1989 PIPE 1990 PIPE

Gutting the airbox increases airflow, while at the same time reducing fuel flow. Carburetors deliver fuel through the needle jets because of the pressure differential between the bottoms of the float bowls and venturi areas under the slides. The stock airbox baffle and foam, necessary for noise reduction (and keeping snow out of the carbs), acts as a restriction which increases the pressure differential. With the foam and baffle gone, we jetted back up to 220 mains to bring the fuel flow and BSFC up to a safe level for 92 octane fuel at 74 degrees F.



PRESENT DURING TEST:
JIM CZEKALA, PETE WEBB,
& RICK BAXTER

STOCK 1990 INDY 650

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STOCK 1990 INDY 650
1990 PIPE 220 MJ Q2 GUT AIRBOX

Data for 29.92 inches Hg. 60 F dry air.

TEST: 100 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .730
VAPOR PRESSURE: .58
BAROMETRIC PRESSURE: 30.26

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
6750	64.2	82.5	56.5	142.7	11.6	.70	73
7000	68.7	91.6	62.6	158.2	11.6	.70	73
7250	71.3	98.4	60.0	167.8	12.8	.62	73
7500	71.1	101.5	61.0	168.8	12.7	.62	74
7750	69.9	103.1	62.3	169.8	12.5	.62	74
8000	67.5	102.8	63.3	169.0	12.3	.63	73
8250	64.2	100.8	62.5	168.0	12.3	.63	73
8500	60.2	97.4	62.9	166.9	12.2	.66	73

It was interesting to note that the addition of the extra breather hose on the mag side of the airbox increased the airflow in both the stock and gutted airbox when compared to the 1989 design. We have seen that the addition of one or even two of these hoses on the mag side of the airbox greatly improves the carburetion of the mag cylinder, especially on modified engines. Apparently, the "jog" in the box where it clears the steering column causes a slight restriction in airflow to the mag carb. The hoses are easily routed to the outside, where cold air can be picked up.

FEEDBACK

JIM CZEKALA

MORE 1990's

We've scheduled a new Arctic Cat Prowler for dyno evaluation in early November--the results should appear in our next issue.

We will also be testing a stock Yamaha V-Max, along with a "factory update ported" version. The V-Max is still available as a new model in Canada, and many Canadian subscribers have expressed interest in this model.

ARCTIC CAT EL TIGRE 6000 (Issue #6)

A large number of subscribers were surprised at the 75 CBHP that our stock engine produced. Because this was the first stock late model El Tigre that we have tested, we cannot be certain that the engine is completely typical.

Some 6000 owners have called claiming success using much smaller main jets than the factory specs suggested. Arctco likes to see their engines jetted at .70 BSFC or more to be "trail safe"; which is where our engine was with the 350 main jets (40 degree F CAT). Like the Wildcat, the El Tigre may benefit greatly from leaner jetting.

For example, local enthusiast Greg Forte checked out his 1980 6000 stocker (500 cc, single pipe) on the dyno this fall, and made 85 CBHP @ .52 BSFC with 240 main jets, ***12 sizes smaller than stock!*** Greg has been very successful dragracing the sled, using 100 LL av gas or better.

If we get the opportunity, we will take another stock late model 6000 and experiment with leaner jetting to determine how much it effects performance

SWAINTECH TBC FOLLOWUP
THERE WAS NO PROBLEM

After our sixth issue went to press, I returned our Phazer pistons to Dan Swain at SwainTech for analysis. They found that the TBC coating was completely intact on the dome of the piston. I had mistaken a smooth, thin layer of beige colored lead deposits on the center of the piston for the TBC coating. The shiny, aluminum colored areas near the intake and transfer areas of the dome were in fact TBC, not bare piston.

When first applied, the TBC has a dull gray-beige hue that can be polished to a silvery finish which very nearly matches the color of the original aluminum base metal. This fooled us into thinking that we were looking at bare aluminum next to the edge of the lead deposit on the piston domes.

I was very surprised to see the lead deposits on the

FEEDBACK

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domes of the pistons after such a short period of dyno testing. During the testing of our high compression Phazer, we had been using 100LL av gas. Even though it's called "low lead", 100LL av gas contains roughly the same amount of tetraethyl lead per gallon as standard racing gasoline.

Lead adhesion to combustion chamber surfaces is normally associated with very high surface temperatures (eg: exhaust valve faces & spark plug electrodes). How could the TBC pistons become lightly coated with lead after such a short time?

Aluminum has tremendous heat absorption qualities, much greater than those of steel or cast iron. Aluminum makes excellent radiators.

Normal combustion chamber heat is absorbed by the pistons and rapidly transferred into the cylinder walls, crankcase, and back into the fresh charge entering the combustion chamber. The actual surface of the piston dome stays relatively hot, due to the continual transfer of heat into and out of the mass of the piston, but is seldom higher than the temperature necessary to precipitate the lead from the gasoline and attach it to the piston surface.

With our TBC pistons, I believe that we are encountering a piston surface temperature "spike" high enough to cause the lead coating. The fact that the combustion chamber heat can't be absorbed as it was previously by the bare aluminum piston mass might cause a brief, slightly higher piston dome surface, or "skin" temperature during the twenty or so degrees of crankshaft rotation where the combustion chamber temperature is at its highest. The fact that there were no lead deposits near the transfer port areas, where piston temperature typically is at its lowest, substantiates this theory.

This temporarily high "skin" temperature of the TBC itself, while it may cause the early formation of lead deposits on the piston dome, seems to be more than offset by the much lower average piston temperature, when compared to uncoated pistons.

What's the bottom line? There was no flaking of the TBC on our piston coating. We cleaned off the lead deposits, and the pistons are ready to reinstall in our Phazer. The day we mistook the lead deposits for TBC flaking, issue #6 of DYNOTECH was going to press; even though I felt that we were receiving a performance improvement from the TBC, I had to report our apparent findings. My apologies to SwainTech and any of our subscribers who may have been inconvenienced or unnecessarily alarmed by our report. Please delete, or black out the "UPDATE" portion of our TBC product evaluation in issue #6.

SPEAKING OF DETONATION

Many subscribers would prefer that we test with "pump gas" instead of "racing fuel". Actually, "racing fuel" is a powerful sounding name for normal gasoline that resists detonation better. All true gasolines, whether they're "pump" or "race", contain the same number of BTU's (ability to generate heat) per pound. There is normally no power advantage from using high octane gasoline, as long as one correctly deals with variations in specific gravity.

The reason we use high octane gasoline is strictly for engine safety, not power production. Virtually all of the engines we test belong to dealers and individuals, so engine protection is one of our primary concerns.

100+ octane fuel affords us the luxury of occasionally "goofing" when testing engines; we can lean down to the point where power drops off, and nothing gets "hurt". Too small a main jet on pump gas usually surprises us with a sickening cessation of both sound and crankshaft rotation. When an engine siezes, it's usually at high RPM, at the point of peak cylinder filling, or peak torque, where an engine is most detonation-prone. Seeing someone else's engine decelerate from 8000 RPM to zero in one second (especially with inertia of a spinning ten pound power absorption unit connected to the crankshaft trying to maintain the engine speed) usually spoils the normally festive atmosphere in the dyno room.

This season we will be experimenting with 100 octane unleaded gasoline being marketed by the Delta-Sonic Car Wash chain. If it truly is 100 octane, and doesn't contain alchohol, we'll use it in our stock engine evaluations. One real benefit of 100 octane unleaded gasoline is the elimination of our exposure to toxic tetraethyl lead, which we absorb through our lungs and skin while testing and changing jets.

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SPEAKING OF SEIZURES

Inside our large toothed belt drive pulley, connecting it to the main driveshaft is a low friction over-running, or "sprag" clutch. The sprag clutch allows us to test engines (such as motorcycles with gearboxes) connected to the main shaft, without spinning the belt and small drive pulley. When we are testing snowmobile engines, we typically run through the toothed belt drive. This decreases the parasitic inertial load of the dyno by 50% on acceleration, and the sprag clutch allows the heavy, spinning dynamometer absorption unit to coast to a stop on deceleration.

Since I've developed an understanding of the BSFC in the engines we test, and our computer displays and updates the BSFC two times per second while we test, piston seizures are very rare. Occasionally, when we're searching for that last elusive horsepower, when we try the smaller diameter stinger, tighter squish, shorter header pipe, or smaller jet, we might "lock one up". That's when we appreciate the sprag clutch.

Imagine the energy stored in a 12" diameter 10 lb. bronze dynamometer absorption unit spinning at engine RPM during an instantaneous siezure. Were it coupled solidly to the engine, it would surely try to rearrange the firing order of the crankshaft! As it is, when the engine stops, the absorption unit is free to coast harmlessly to a stop.

EXTREMELY NIFTY TUNING TOOL

Jack Hull, of L. Hull Sales in Mayville, N.Y. sent us a portable digital tachometer, model DET-302 sold by Stihl Chainsaw dealers. The portable digital tach has a self contained battery, and is connected to any engine with an alligator clip attached to a spark plug lead.

Designed for single cylinder engines, the tach displays twice the RPM on a two cylinder, and three times the RPM on a triple.

As has been the case with every aftermarket digital tach we have tested, the Stihl unit reads exactly the same as our digital dynamometer tach. For example, at 9000 true RPM a Polaris triple would read 27000 RPM.

The tach readout is relatively small, but perfect for static calibrating those occasionally lousy factory tachs on your engine. The good news is that the tach retails for well under a hundred bucks. You've got to know where your power peak is on your tach. Thanks, Jack.

FUEL INJECTION FOR THE 90's

As this issue is going to press, Polaris has announced the introduction of their Electronic Fuel Injected "RXL 650". A limited release of 500 sleds will have, along with the fuel injection, newly designed cylinders (evidently the ones that were rumored to be used on all of the 1990 650 stockers) that should provide improved performance. Kevin Cameron is following up on the details that hopefully will be included in the next issue.

We are eagerly awaiting the arrival of the first RXL for dyno analysis. We will feed it cold air, and warm air, and we'll see what sort of H.P. and BSFC the factory will allow us to have!

SPEAKING OF FUEL INJECTION

The December issue of Cycle Magazine has a comprehensive article (written by Kevin Cameron) on an aftermarket fuel injection system designed by DynoJet in Montana (406-388-4993). This is a tuneable add-on unit that senses mass airflow into the engine.

They are currently working on an aftermarket snowmobile unit, and may have something for us to test later this season.

MACH I

Gary Potyok was pleased with the performance of the **DYNO*TECH*** Mach I this past winter. The Mach I was the fastest sled at the Minden Ontario Formula Club ride and also at the Bombardier Ontario Dealer ride with a radar verified speed of 105 MPH. The sled ran last season setup as in the 108 HP hop-up article with 13.7/1 head, 44 carbs, but with the addition of FAST twin pipes.

Gary ran trouble free 100+ miles with one mild seizure that could have been avoided if he would have believed his exhaust temperature gauges.

Fuel used for the season was 4 gallons of 100/130 green AV gas to 1 gallon of 92 octane pump gas.

For the coming season Gary has added a 15.1/1 head, 46 carbs and plans to install a FAST tunnel ported bottom end. We hope to do some update testing and will report on the performance of this combination after the snow falls.

COMPRESSION RATIOS

BY TIM TAYLOR

When tuning a two-stroke engine for performance, one of the modifications considered first is milling the cylinder head to reduce the squish band clearance. The squish band is an annular ring around the perimeter of the combustion chamber that makes up approximately 50% of the total area of the combustion chamber. This annular area has a relatively small clearance between the combustion chamber roof and the piston dome and its function is to control detonation during the combustion process. The portions of the air-fuel mixture around the perimeter of the combustion chamber are referred to as end gases. If the temperature of the end gases can be controlled during the combustion process then detonation will not occur. After the combustion process starts, the temperature in the combustion chamber begins to rise rapidly. Because the end gases are trapped in the narrow squish band, they are able to transfer heat to the cooler cylinder head rapidly and therefore don't get hot enough to ignite. At this point we need to realize that this unburnt fuel in the squish band may make up as much as 20% of the total fuel charge and as it does not contribute to the combustion process, it does not produce any power in the engine.

Manufacturers have designed squish bands that are wider than optimum to allow for a problem called "tolerance stack up" that occurs in mass produced assemblies consisting of many components. A designer will layout the component parts at their extreme tolerance and then calculate the minimum squish band required for this extreme condition. The result is a squish band that is functional and safe from a manufacturing standpoint, but not optimum for performance. By milling the head we can reduce the volume of the squish band, reduce the amount of unburned fuel, produce more power and control detonation.

Milling the head not only reduces the squish band clearance, but also reduces the total volume of the combustion chamber thereby raising the compression ratio of the engine which may require higher octane fuel. Since we are tuning for performance we probably would be planning to raise the compression ratio anyway, but to what level will depend on the intended use of the sled and the fuel available. At this point we need to calculate our compression ratio to determine if more work needs to be done to the head and find out what our fuel requirement is going to be.

To calculate the compression ratio of an engine we use the following formula:

$$\textbf{Compression ratio} = \frac{CV + CCV}{CCV}$$

WHERE:

$$CV = \frac{\text{cyl. bore}^2\ (\text{mm}) \times \text{Stroke (mm)} \times .7854}{1000}$$

CV = Cylinder Volume (cc's)
CCV = combustion chamber volume as installed (cc's)

The values for bore and stroke are available in most owner's manuals, however the value for installed combustion chamber volume is usually listed only in the service manual. If material has been milled from the head then the value listed in the service manual is no longer valid and the combustion chamber volume must be determined using a chemist's buret. A buret is a graduated cylinder (in c.c.'s) with a petcock on the bottom used to control the flow of the measuring fluid used to check the volume of the combustion chamber. At this point it is important to note that the combustion chamber volume **must** be checked with the head installed and torqued to the cylinder with a head gasket. This method will take into consideration the volume of the head gasket and the amount the piston is above or below the cylinder deck.

To begin checking the combustion chamber volume you must first remove the head and remove all traces of carbon deposits from the piston dome and combustion chamber. After this, rotate the crankshaft until the piston dome is down in the cylinder bore an inch or so and smear a small amount of white grease around the circumference of the piston dome. Rotate the crankshaft to bring the piston up to to dead center and wipe off the excess grease. Install the head gasket and cylinder head while making sure the piston stays top dead center while torquing down the head bolts. Mount the buret in a clamp and mix a 50/50 mixture of injection oil and stoddard solvent and fill the buret above the zero line. Wait a minute or so for all the air bub-

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COMPRESSION RATIOS

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bles to rise to the top of the buret and open the petcock to drain off enough fluid to reach the zero line. Place the buret over the spark plug hole and fill the combustion chamber with the buret fluid to just slightly below the bottom of the plug hole. Rock the crankshaft back and forth slightly while observing the fluid at the bottom of the plug hole. Stop rocking the crankshaft when the fluid is at its highest level and add enough fluid with the buret to bring the level up even with the bottom of the plug hole. Close the petcock and read the combustion chamber volume directly from the graduations on the buret.

It is also important to know what the actual squish band clearance is on your engine before you go and have the head milled. This can be checked very easily using a short length of 3/32 solder. After you have cc'd the combustion chamber rotate the crankshaft to let the buret fluid run out of the exhaust port. Bend the solder into an L shape and insert it into the cylinder bore through the spark plug hole. Make sure the end of the solder is touching the cylinder wall and rotate the crankshaft to bring the piston around past top dead center. Repeat this procedure several times at several locations in the same bore because you want to make sure you have found the minimum clearance. This will flatten the solder out and you will be able to measure the installed squish band clearance directly from the end of the solder using a micrometer or a pair of calipers. Be sure to measure the solder at the very edge where the squish band is the tightest.

To show how you use the formula to calculate compression ratio we will use the data from a Polaris Indy 650. The 650 has a bore of 67.72mm and a stroke of 60mm. Using the formula given above for cylinaer volume we find that the indy has a volume of 216.11 cc's per cylinder.

$$\frac{67.72^2 \times 60 \times .7854}{1000} = \frac{4586 \times 60 \times .7854}{1000} = \frac{216110}{1000} = 216.11$$

The Polaris Repair Manual gives the installed combustion chamber for the 1989 650 as 21.0 cc's. Using the formula given above for compression ratio we find that the 1989 650 Indy has a compression ratio of 11.3 to 1.

$$\frac{216.11 + 21}{21} = \frac{237.11}{21} = 11.29 \text{ or } 11.3 \text{ to } 1$$

This compression ratio number is the traditional way most of us think of compression ratio especially if we have a hot rodding background. In two-stroke circles this is referred to as uncorrected compression ratio. Some two-stroke tuners will use what is referred to as a corrected compression ratio. The formula for corrected compression ratio uses the length of piston stroke from the top edge of the exhaust port to TDC. This is called the effective length of stroke as the piston cannot begin to compress the fuel charge until the exhaust port has closed. On a stock Indy 650 this dimension will be approximately 31mm. Using the same formula given above for compression ratio except the effective piston stroke in place of the full stroke dimension gives us a corrected compression ratio of 6.3 to 1.

$$\frac{67.72^2 \times 31 \times .7854}{1000} = \frac{4586 \times 31 \times .7854}{1000} = \frac{111657}{1000} = 111.66$$

$$\frac{111.66 + 21}{21} = \frac{132.66}{21} = 6.31 \text{ or } 6.3 \text{ to } 1$$

While we are talking about compression ratio and effective lengths of stroke we should point out that two-stroke tuners will also monitor the cranking pressure of a motor with a compression tester. Cranking pressures will range from 120 psi in a stock motor to 170 psi and above for wild full mod motors. All of this really isn't so cut and dry because the effect of the pipe and the strength of the return pulse coming up the pipe have an effect on the filling of the combustion chamber. The best thing that you can do is not go milling your head carelessly, but follow some well developed guidelines published by your sled manufacturer or the **DYNO*TECH*** pipe shootouts.

Tim Taylor is a recent addition to **DYNO*TECH***'s consultation staff. He has an Associates Degree in Agricultural Engineering from the State University of New York and has spent seven years desigining and testing electro-hydraulic control systems. Tim lives in Waterloo, N.Y. where he farms 2000 acres.

THE DAY OF THE WORM EATERS

THE CELLAR DWELLER KEVIN CAMERON

Are you tired of being considered slightly odd because you use and enjoy two-stroke engines? Could you do without ever again seeing one of those T-shirts that proclaim, **"I'd rather eat worms than ride a two-stroke"?** The day of the worm-eating has come; the two-stroke engine is now the hottest item on the auto makers' agenda. Every major car maker has a two-stroke engine project in progress. Ford, General Motors, and Mercury Marine have all licensed the new air-driven fuel injection technology from Australia's Orbital Engine Company, and are testing various two-stroke configurations. The French Peugeot firm is testing a stratified-charge two stroke. Chrysler's two-stroke is wet-sump but has cylinder-wall ports, and uses Siemens-Bendix fuel injection.

Subaru is testing a 1.6 liter, blower-scavenged two-stroke that is giving 176 BHP (this compares with a 350 Chevy making 630 BHP). Toyota's two-stroke, likely to appear in trucks in 1993, uses cam-driven intake and exhaust valves in its head, with scavenge air supplied by separate roots blower in Detroit-Diesel fashion (scavenging is the process of clearing the cylinder of exhaust products by blowing through it). Although based on a pre-existing four-stroke, four liter, six cylinder block, this engine reputedly gives just under 500 foot pounds of torque at very low, Diesel-like RPM. Remember the old 455 Olds engine in the 442? That 7.5 liter engine gave just 500 foot-pounds of torque.

Other firms in Italy, Taiwan, Austria, and Germany are also proceeding with two-stroke automotive engine development.

Major fuel systems manufacturers, and some new firms besides are tackling the problems of high speed two-stroke fuel injection.

Why is this happening? Any future powerplant will have to meet emissions and fuel economy standards, yet provide sporting performance combined with high driveability. The four-stroke engine has been squeezed hard to deliver all this, and it's running into trouble. The add-ons that deliver extra performance--four-valves-per-cylinder, electronic engine management systems, variable cam timing, and engine counter-balancers--all add cost, complexity, and weight. Getting more power means either raising combustion pressure or RPM. Raising the pressure means higher flame temperatures and the NOx that produces. Raising the RPM means engines have to be made more rigid and need special measures for balancing. Isn't there an easier way?

For years, the two-stroke engine was an outcast because of its high emissions of unburned hydrocarbons. So long as these engines, with fuel-air mixture, and not with pure air as Diesels are, this problem could not be solved. Some fresh charge always short-circuited to the exhaust, unburned. Although there is no reason why two-strokes cannot be built with wet sumps like four-strokes, and get their scavenge air from separate blowers, most existing two-strokes used their crankcases as scavenge pumps. This in turn meant that only rolling-element bearings could be used for crank main and rod big-end bearings. Such bearings rust easily during engine shut-down periods unless certain kinds of oils are used, and wear rapidly in the presence of any dirt in the intake air. Auto engineers shy away from problems like these.

However, there has never been anything wrong with the power, torque, lightness, simplicity, or cheapness of two-strokes. By firing twice as often as a four-stroke, a two-stroke avoids the need to turn very high RPM to make power. The simplest varieties have a bare minimum of moving parts.

Ten or fifteen years ago some experiments were made with fuel injection on crankcase scavenged two-strokes, and it was found that fuel use could be cut 40%, and emissions with it, by injecting the fuel after there was no longer time for it to reach the exhaust port before it closed. This work was interesting, but at the time academic. Fuel injection cost a lot of money, four-strokes were dominant, and no one was interested.

In the meantime, emissions laws grew tougher, and to meet them even four-strokes were forced to adopt highly accurate (and expensive) electronic fuel injection. If four-strokes now needed injection, it was no longer a handicap that two-strokes needed it. The wheels began to turn.

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WORM EATERS

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In the early 1980's a company in Australia--Orbital Engine Co.--revived and improved the earliest concept in Diesel injection--that of injecting the fuel in a supersonic jet of high pressure air. One of the problems with direct cylinder fuel injection in spark-ignition engines is that there is too little time for the fuel to evaporate from droplets to form a spark-ignitable vapor. Unless everything was exactly right, direct injection worked less well than carburetors. With the Orbital air-driven injector, however, 90% of fuel droplets were under 10 microns in diameter, (.0004"), and their system worked well on two or four-stroke engines. Orbital is presently equipping a production plant in the USA to manufacture complete two-stroke engines for automotive, marine, and industrial applications.

The orbital developments were the opening move in what has since turned into a major shift in technology. There is enormous variety in the two-stroke concepts now being explored. Small, crankcase-scavenged, cylinder ported engines have been made to pass EPA, but bigger ones with separate scavenge blowers and mechanical valves offer the possibility of enormous torque and power; once there exhaust valves have closed, they can be supercharged far above atmospheric pressure. Thus, the only limit to power is detonation and piston temperature. In addition to Orbital's well publicized air-driven injector, there are other fuel systems coming which achieve similar results without air drive, using high injector pressure. Air-drive injectors appear best for light-load applications (such as a 55 MPH auto) while solid injection may be best for high-load duty such as marine and industrial service.

Meeting emissions has so far not been a problem for the new two-strokes. The hardest pollutant to deal with is nitrogen oxides (NOx), a major element in smog formation. Four-stroke engines need high charge purity to make power, but the means high combustion temperature which generates NOx. Two-strokes, on the other hand, have natural exhaust-gas recirculation (EGR), which dilutes the charge, thereby reducing its flame temperature. Where a four-stroke has an exhaust stroke to clear its cylinders of exhaust gas, the new automotive two-strokes will blow down their exhaust somewhat BTDC, then refill the cylinder under pressure from the scavenge blower as the piston rises on compression. The fill process therefore entrains considerable exhaust gas.

Some of these new two-strokes can meet EPA specs using only an oxidizing exhaust catalyst, without using closed-loop fuel control via an oxygen sensor, with a reducing catalyst. The larger engines will probably have emissions controls like those currently used on four-strokes.

Fuel consumption of these new two-strokes may be as good as that of automotive Diesels--the result of stratified-charge combustion systems which present a rich, easily-ignited mixture to the spark plug, but fill most of the cylinder with a far leaner mix.

The significance of these automotive developments is that fanciers and users of two-stroke engines can take heart; technologies are coming that will make two-strokes at least as clean as the current crop of four-strokes, and bring improved fuel consumption and better response as well. Once major auto makers have EPA-certified their new two-strokes, a major barrier to their acceptance will have been pierced. If two-strokes reach production for automobiles, their continued acceptance in outboards, motorcycles, and snowmobiles is assured, and the technology to make these devices meet any forseeable emissions standards will have been funded in advance.

The next time your car-nut friends rib you about your affection for the two-stroke, suggest they go cut wood with a four-stroke chainsaw.

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