Volume 2 Number 2 1990

DYNOTECH

THE SNOWMOBILE PERFORMANCE PUBLICATION

PIPE SHOOTOUT #9

MODIFIED PHAZER

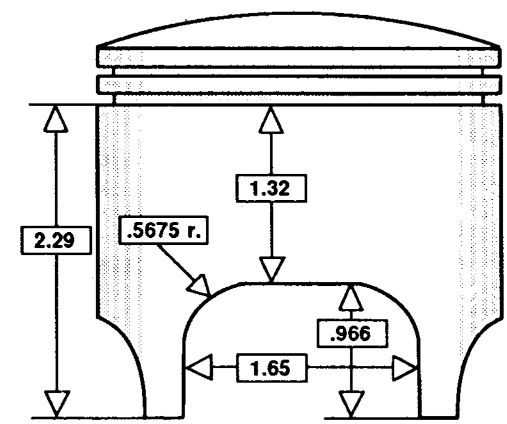
The modified Phazer that we used for our ninth pipe shootout was one of the many 80+ CBHP Bender "clones" that have proliferated Western New York. Bender's Phazer porting is very similar to the Phazer porting that we have had the opportunity to examine by Aaen, Reichard, and PSI. With the Bender Racing combination, the exhaust port is widened and polished, transfers cleaned up, and intake altered mostly by the use of an "SX" style piston cut (see drawing). The SX piston cut was developed by Yamaha for Formula 56 oval racing, and has proven to be a consistent four horsepower add-on for any Phazer--even with the stock pipe.

The heads had the squish bands relieved to .090 clearance, then the .029" thick head gaskets were removed. Bolting the heads directly to the cylinders with a light coating of silicone sealer left us with a net .061" squish and higher compression. This particular engine used the stock reeds, stock butterfly carbs, Dial-a-Jets and gutted airbox. Such a combination is fine for improved stock dragracing on 100 octane gasoline, but difficult to trail ride because of high compression and midrange leanness.

For trail riding on pump gas, the head gaskets are reinstalled with a stock airbox. **Remember: if it "pings", let off the throttle and jet up or you will be buying new piston(s)!**

The pipes used for this Shootout include the Aaen Quiet Can and Single Silencer pipes, PSI's single and twin pipes, Decker's single pipe, and Reichard Yamaha's new single pipe as well as their cut stock pipe.

During our test session, the Carb Air Temperature was in the 70's. 100 LL Aviation fuel was used throughout the test, and the oil injection was retained.



"SX" PISTON - INTAKE SKIRT MOD.

This first set of data was obtained with the stock Y pipe, 150 main jets, and the Dial-a-Jets as indicated to achieve a similar A/F ratio and BSFC.

STOCK PIPE 150mj DJlean 88dB
Data for 29.92 inches Hg. 60 F dry air.

TEST: 100 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .715
VAPOR PRESSURE: .58
BAROMETRIC PRESSURE: 30.26

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
5000	31.8	30.3	24.2	75.9	13.1	.82	75
5250	34.2	34.2	25.2	84.0	15.3	.75	73
5500	38.2	40.0	28.5	93.0	15.0	.73	75
5750	43.7	47.8	32.9	103.0	14.4	.71	74
6000	46.9	53.6	35.4	109.2	14.2	.68	76
6250	49.0	58.3	40.1	114.5	13.1	.70	74
6500	49.3	61.0	42.6	116.9	12.6	.72	74
6750	49.0	63.0	42.6	117.2	12.6	.69	74
7000	47.2	62.9	42.1	116.6	12.7	.69	74
7250	43.7	60.3	42.2	114.8	12.5	.72	74
7500	39.8	56.8	40.1	111.6	12.8	.73	75
7750	35.4	52.2	39.5	109.7	12.8	.78	73

PIPE SHOOTOUT

CONTINUED FROM PAGE 1

PSI SINGLE PIPE 150mj DJlean 90dB
Data for 29.92 inches Hg. 60 F dry air.
TEST: 100 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .715
VAPOR PRESSURE: .58
BAROMETRIC PRESSURE: 30.26

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
5500	42.9	44.9	32.7	92.4	13.0	.74	70
5750	42.1	46.1	33.3	94.6	13.0	.74	70
6000	44.6	51.0	33.7	100.0	13.6	.68	70
6250	47.5	56.5	35.6	104.1	13.4	.64	70
6500	51.6	63.9	39.2	110.4	12.9	.63	70
6750	54.2	69.7	41.2	113.7	12.7	.60	72
7000	56.5	75.3	44.6	118.1	12.2	.60	70
7250	56.4	77.9	45.1	119.7	12.2	.59	71
7500	54.7	78.1	45.3	121.1	12.3	.59	68
7750	52.2	77.0	45.1	121.0	12.3	.60	70
8000	42.0	64.0	43.4	117.8	12.5	.69	70

PSI TWIN PIPES 150mj DJlean 92dB
Data for 29.92 inches Hg. 60 F dry air.
TEST: 100 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .715
VAPOR PRESSURE: .58
BAROMETRIC PRESSURE: 30.26

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
6000	50.1	57.2	38.4	111.6	13.3	.68	69
6250	52.1	62.0	39.0	113.8	13.4	.64	69
6500	53.6	66.3	42.6	115.1	12.4	66	71
6750	55.2	70.9	44.1	117.4	12.2	.64	72
7000	54.5	72.6	45.9	118.8	11.9	.64	71
7250	54.1	74.7	47.7	120.0	11.6	.65	71
7500	54.1	77.3	47.2	122.3	11.9	.63	72
7750	53.2	78.5	45.6	124.6	12.5	.59	71
8000	50.1	76.3	45.6	124.6	12.5	.61	71
8250	36.5	57.3	44.4	116.8	12.1	.79	70

DECKER SINGLE PIPE 150mj DJrich 90dB
Data for 29.92 inches Hg. 60 F dry air.
TEST: 100 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .715
VAPOR PRESSURE: .58
BAROMETRIC PRESSURE: 30.26

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
5750	31.8	34.8	22.2	65.2	13.5	.65	73
6000	34.9	39.9	22.9	70.0	14.0	.59	74
6250	47.9	57.0	33.4	101.0	13.9	.60	72
6500	52.4	64.9	38.2	109.0	13.1	.60	71
6750	54.5	70.0	40.9	111.9	12.6	.60	72
7000	54.8	73.0	42.5	113.6	12.3	.60	73
7250	53.4	73.7	43.3	113.6	12.0	.60	72
7500	50.8	72.5	42.5	113.5	12.3	.60	72
7750	38.0	56.1	38.8	109.4	12.9	.71	72

REICHARD SINGLE PIPE 150mj DJrich 90dB
Data for 29.92 inches Hg. 60 F dry air.
TEST: 100 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .715
VAPOR PRESSURE: .58
BAROMETRIC PRESSURE: 30.26

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
6750	52.3	67.2	39.2	109.1	12.8	.60	72
7000	53.4	71.2	41.6	113.3	12.5	.60	73
7250	52.9	73.0	43.4	113.7	12.0	.61	73
7500	52.0	74.3	42.1	113.9	12.4	.58	73
7750	49.7	73.3	41.4	113.5	12.6	.58	72
8000	45.5	69.3	41.8	111.8	12.3	.62	72

REICHARD CUT STOCK PIPE 150mj DJlean 88dB
Data for 29.92 inches Hg. 60 F dry air.
TEST: 100 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .715
VAPOR PRESSURE: .58
BAROMETRIC PRESSURE: 30.26

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
5500	43.2	45.2	31.2	95.1	14.0	.70	70
5750	43.9	48.1	31.5	98.8	14.4	.67	69
6000	46.5	53.1	35.4	104.9	13.6	.68	70
6250	48.9	58.2	37.8	109.5	13.3	.66	70
6500	50.4	62.4	40.2	113.4	13.0	.66	70
6750	51.9	66.7	41.4	117.3	13.0	.63	70
7000	51.5	68.6	42.5	119.5	12.9	.63	68
7250	50.7	70.0	43.0	119.2	12.7	.63	69
7500	48.2	68.8	42.6	118.8	12.8	.63	69
7750	44.3	65.4	41.8	118.1	13.0	.65	70
8000	35.6	54.2	41.7	114.5	12.6	.79	71

AAEN SINGLE SILENCER PIPE 150mj DJrich 90dB
Data for 29.92 inches Hg. 60 F dry air.
TEST: 100 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .715
VAPOR PRESSURE: .58
BAROMETRIC PRESSURE: 30.27

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
6000	44.6	51.0	30.9	95.5	14.2	.62	70
6250	51.9	61.8	37.2	108.3	13.4	.61	66
6500	55.1	68.2	41.5	113.3	12.5	.62	69
6750	57.8	74.3	42.9	117.4	12.6	.59	71
7000	58.5	78.0	45.9	121.0	12.1	.60	70
7250	57.8	79.8	46.7	122.9	12.1	.60	70
7500	55.2	78.8	46.6	124.1	12.2	.60	70
7750	48.6	71.7	45.8	124.0	12.4	.65	70
8000	31.6	48.1	44.8	112.3	11.5	.95	71

AAEN QUIET CAN PIPE 150mj DJrich 90dB
Data for 29.92 inches Hg. 60 F dry air.
TEST: 100 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .710
VAPOR PRESSURE: .58
BAROMETRIC PRESSURE: 30.26

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
6000	47.4	54.2	32.4	98.9	14.0	.61	70
6250	50.4	60.0	36.6	104.5	13.1	.62	70
6500	51.8	64.1	39.1	108.4	12.7	.62	70
6750	56.1	72.1	41.3	113.9	12.7	.58	70
7000	56.6	75.4	42.8	116.8	12.5	.58	70
7250	57.5	79.4	44.6	119.8	12.3	.57	70
7500	56.7	81.0	45.9	121.4	12.1	.58	72
7750	52.2	77.0	44.8	121.9	12.5	.59	72
8000	32.6	49.7	42.1	110.5	12.1	.87	71

We also have experimented on several occasions with shorter Y pipes on the Phazer. Our tests have indicated that, with most pipes, removing as little

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PIPE SHOOTOUT

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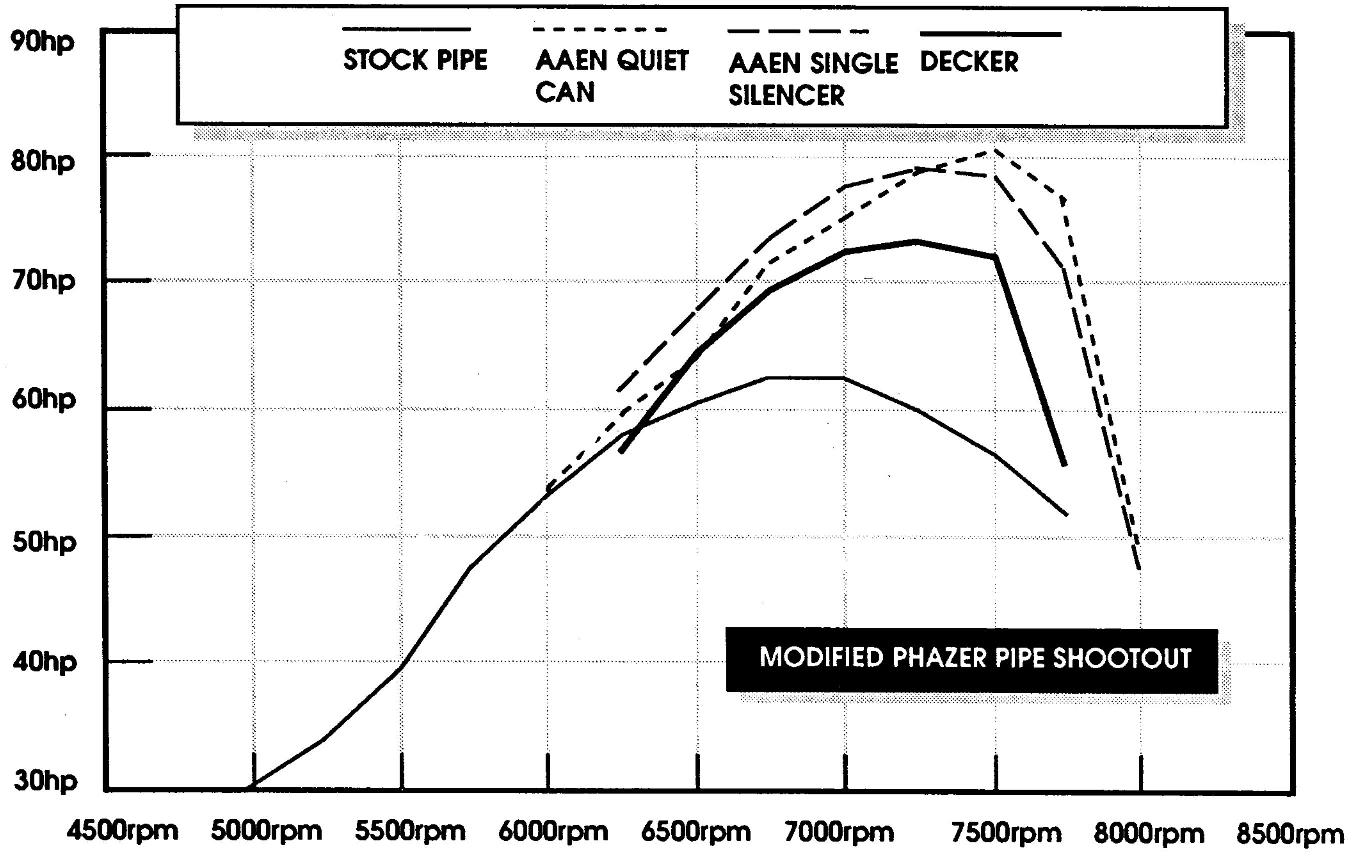
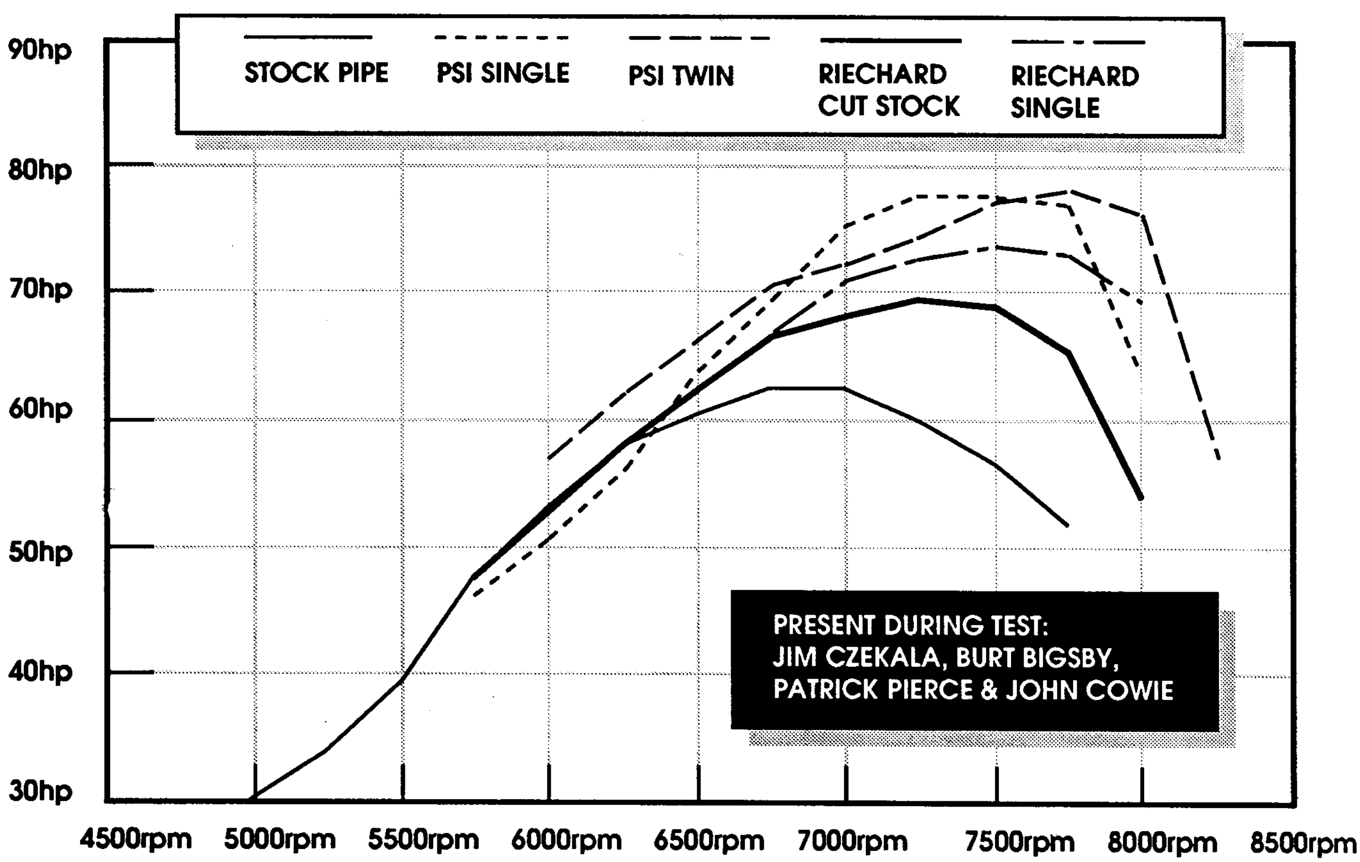




PIPE SHOOTOUT

CONTINUED FROM PAGE 3

as 1/8" to 3/16" adds one to two CBHP at a peak RPM, usually sliding the peak up 250 RPM. The exception being the Aaen Quiet Can pipe, which usually makes the best power with the stock Y pipe.

Also, on our single Phazer pipes, the fiberglass packing is critical. Burned out packing, besides making more noise, typically costs two CBHP at peak.

Cold air induction kits, sold by Aaen, Bender, and others are also very beneficial; trading what is typically 80+ degree underhood air for cold outside air is worth lots of free horsepower.

Mikuni 38mm flatslides are a popular add-on for the Phazer. Their main benefit is midrange tunability, and they offer slightly higher airflow when used with a gutted airbox. Unless the airbox is gutted, there is no power to be gained with these carbs. For winter operation, we find that Q8 or R0 needle jets are necessary.

With our Aaen Quiet Can pipe still in place, we installed a set of the 38mm flatslide carbs. The following test was typical of the runs we made with the larger carbs. We did run some of the other single and twin pipes with the larger carbs, and the power improvement was similar.

AAEN QUIET CAN 38 Flatslides Q6nj 220mj
Data for 29.92 inches Hg. 60 F dry air.
TEST: 100 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .715
VAPOR PRESSURE: .58
BAROMETRIC PRESSURE: 30.32

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
6000	47.6	54.4	35.7	101.6	13.1	.67	75
6250	51.1	60.8	36.2	105.8	13.4	.61	76
6500	52.9	65.5	36.3	109.9	13.9	.57	77
6750	56.8	73.0	41.9	115.4	12.6	.59	76
7000	58.6	78.1	39.1	119.7	14.1	.51	76
7250	58.4	80.6	42.3	121.2	13.2	.54	77
7500	57.1	81.5	39.5	122.8	14.3	.50	77
7750	52.3	78.7	37.3	123.1	15.2	.48	76

Replacing the stock reeds with a set of Boyeson fiber reeds gave us additional airflow and horsepower in the midrange as well as top end.

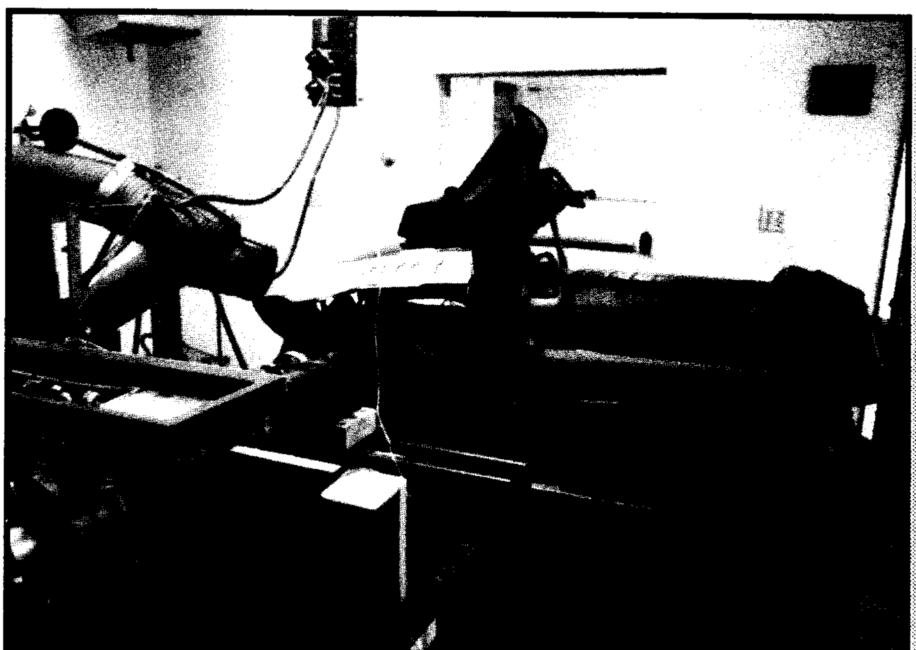
AAEN QUIET CAN 38 Flatslides Boyeson reeds
Data for 29.92 inches Hg. 60 F dry air.
TEST: 100 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .715
VAPOR PRESSURE: .52
BAROMETRIC PRESSURE: 30.31

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
6000	48.6	55.5	32.9	101.0	14.1	60	75
6250	52.6	62.6	39.2	107.8	12.6	.64	73
6500	54.6	67.6	38.1	112.3	13.5	.57	73
6750	57.6	74.0	39.4	116.9	13.6	.54	74
7000	60.2	80.2	37.4	121.7	14.9	.48	74
7250	60.1	83.0	40.2	124.0	14.2	.50	75
7500	58.6	83.7	45.0	126.3	12.9	.55	75
7750	53.3	78.7	45.6	126.5	12.7	.59	74

1990 ARCTIC CAT PROWLER

The stock Prowler set up and tested "In Chassis" on the C&H Dyno.

A full Pipe Shootout will be undertaken on this sled when pipes become available. Also, a future article will address Performance Improvements.



1990 PROWLER

The 1990 Arctic Cat Prowler that we chose for this evaluation was well broken in, with several hundred miles on it's odometer. Testing this new model "in-chassis" was simplified by the presence of removable side panels (like the Phazer) that allow quick access to the crankshaft. In addition, we removed the seat to allow installation of our airflow meter to the stock airbox. 92 octane unleaded gasoline was used throughout the evaluation.

The Prowler's 34mm carbs were fitted with 230 main jets to compensate for our mid-fifty degree F. Carb Air Temperature. After a thorough warm-up and part throttle check-out (everything appeared fine), we performed several dyno runs to establish a baseline. The following data is typical of our baseline tests.

STOCK BASELINE 230 main jets
Data for 29.92 inches Hg. 60 F dry air.
TEST: 100 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .750
VAPOR PRESSURE: .38
BAROMETRIC PRESSURE: 30.04

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
4870	25.8	23.9	27.6	64.7	10.8	1.17	60
5750	39.9	43.7	30.0	92.8	14.2	.69	58
6000	40.4	46.2	35.0	96.2	12.6	.76	58
6250	42.6	50.7	41.3	102.5	11.4	.82	57
6500	43.5	53.8	43.2	104.9	11.2	.81	57
6750	43.4	55.8	45.7	105.7	10.6	.82	57
7000	43.0	57.3	50.3	106.0	9.7	.88	57
7250	41.5	57.3	50.3	105.4	9.6	.88	58
7500	39.2	56.0	46.9	105.2	10.3	.84	57
7750	35.6	52.5	43.8	105.1	11.0	.84	57
8000	31.1	47.4	39.8	104.6	12.1	.85	57
8250	26.3	41.3	37.1	102.4	12.7	.91	59

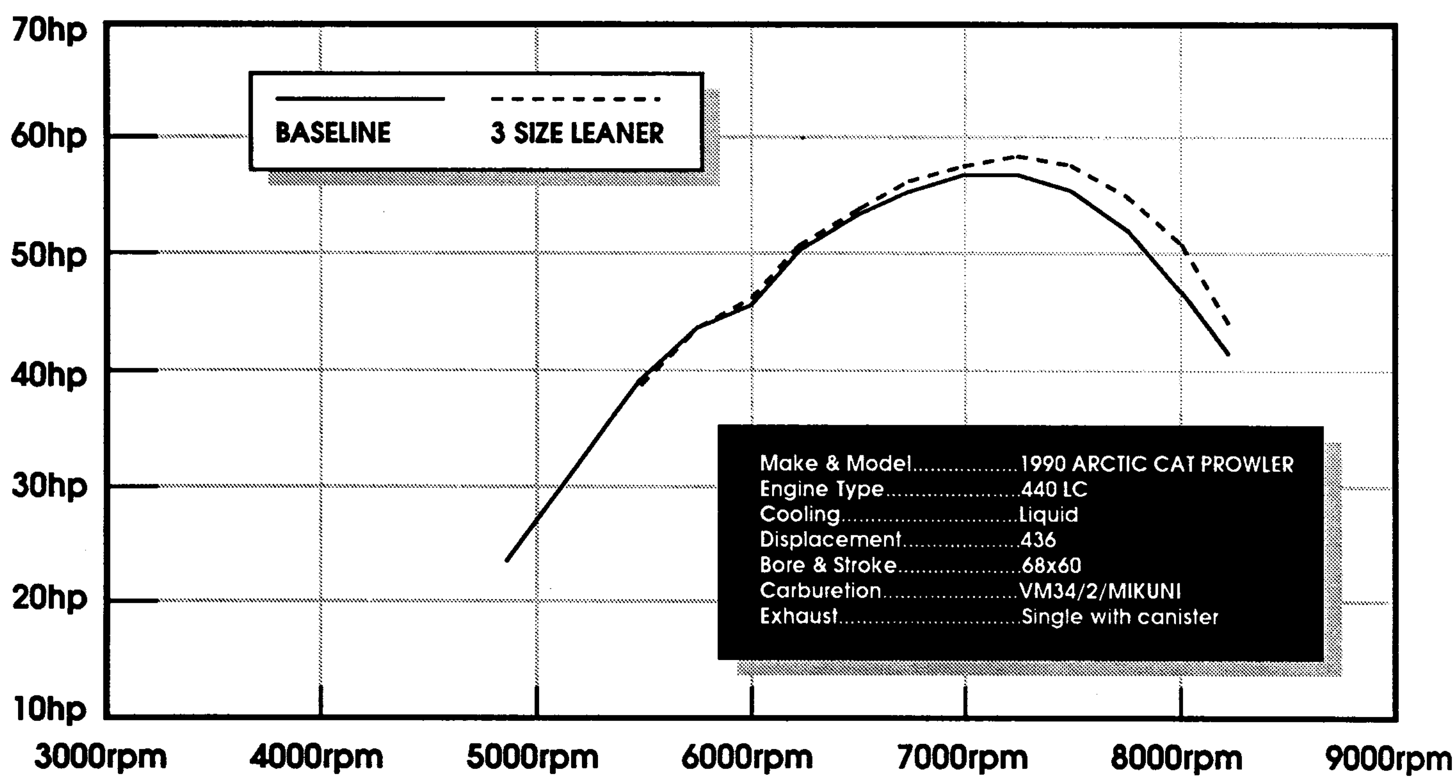
Because the BSFC was so safe and rich (in the mid eighties), we dropped the main jets to 200. This brought the BSFC down into the high sixties, and resulted in a corresponding power increase to approximately 60 CB-HP. **Remember that this jet spec is based upon our CAT of 55 degrees F. at 500 ft altitude, on 92 octane gas.**

The owner of this sled has chosen 230 main jets for his winter riding, which have proven safe to 15 degrees F. at sea level.

After completing our dyno evaluation, we weighed the Prowler on our commercial Toledol scale--With two gallons of gas and a full tank of oil, it weighed 460 lbs.

THREE SIZE LEANER 200 main jets
Data for 29.92 inches Hg. 60 F dry air.
TEST: 100 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .750
VAPOR PRESSURE: .38
BAROMETRIC PRESSURE: 30.06

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
5500	37.4	39.2	31.1	86.9	12.8	.80	55
5750	40.0	43.8	32.9	92.9	13.0	.75	55
6000	40.7	46.5	34.6	96.5	12.8	.75	56
6250	42.9	51.1	40.8	102.3	11.5	.80	56
6500	43.8	54.2	43.2	104.7	11.1	.80	56
6750	44.2	56.8	44.1	106.6	11.1	.78	55
7000	43.5	58.0	42.6	107.2	11.6	.74	55
7250	42.7	58.9	40.7	106.4	12.0	.69	56
7500	40.6	58.0	40.8	105.9	11.9	.71	56
7750	37.6	55.5	38.7	105.6	12.5	.70	57
8000	33.5	51.0	38.1	105.5	12.7	.75	57
8250	27.9	43.8	39.1	103.9	12.2	.90	57



EXERCISE IN EXCESS

NITROUS OXIDE (N_2O) JIM CZEKALA

"ON THE BOTTLE"
"SHOOTING JUICE"
"ON THE BUTTON"
"ON SPRAY"
"ON THE LAUGH"
(a Canadian favorite)

There are probably many other nicknames for this major performance enhancer, or "equalizer" that has been gaining popularity with lake racers and dragracers.

To demonstrate the horsepower producing capabilities of N2O injection, we used a stock 1990 Mach 1 that had a NOS brand kit installed by Dennis Johnson. Denny owns Kuyahoora, a Ski-Doo dealership in Poland, N.Y. (315-826-3312). They are also warehouse distributors for NOS brand kits.

The typical Nitrous Oxide injection kit consists of a small aluminum high pressure cylinder (usually with a capacity of from 1 to 5 lb.), an auxiliary electric fuel pump, a pair of 12VDC solenoids to control the N2O and extra fuel, and individual nozzles for each of the engine's cylinders. A normally open, momentary switch is used to energize the system. The typical snowmobile electrical system operates on 12VAC, so a 12V battery is usually necessary to operate the electric components.

On our test sled, instead of a 12V battery, Denny installed a full wave bridge rectifier to extract the DC voltage necessary to operate the system.

Nitrous Oxide, or N2O, is a compressed gas commonly used by the medical profession as an anesthetic. It is stored as a liquid in high pressure cylinders at @800 psi, at room temperature. Containing 33% oxygen (as opposed to 20% for normal air), N2O, when released to atmospheric pressure, vaporizes from a liquid to a gas at a very dense -100 degrees F.

N2O by itself does not burn; it only supports combustion. When N2O is injected into an engine, additional fuel must be simultaneously injected--this is how the extra horsepower is developed.

One very nice feature of the NOS brand kits is their use of "fogger nozzles" which combine the N2O and fuel into one nozzle. Fogger nozzles feature easily changeable orifices, or "pills" to alter the amounts and ratios of N2O and fuel.

Tuning Nitrous Oxide systems on our dyno is especially enjoyable; seldom are we rewarded with such dramatic power gains with so little effort. We test N2O only with ultra high octane fuel. A slight miscalculation in N2O/fuel ratios, especially in large volumes, can easily detonate the engine. The use of 110+ octane fuel and rapid acceleration tests allows us to experiment with large nozzle sizes with relative safety.

With the Mach 1 set up and running on the dyno (we tested the engine in the chassis), it became apparent that the engine was in less than perfect condition. After warmup, our initial baseline tests showed that the engine was developing only 90 CBHP--far from the stock 1990 Mach 1's typical 100 CBHP. Checking the engine with a leak-down tester revealed a 20% loss of ring-seal on one cylinder. Had this been anything other than an N2O "exercise in excess", the engine would have been unuseable in this condition. As evidenced in the accompanying data, the poor ring seal was more than amply made up for by the NOS kit.

While examining this data, please keep in mind several critical factors.

1. There is no truly pump gas safe BSFC when N2O is used.

2. N2O cylinder temperature is extremely critical. Our nozzle sizes were correct only for the temperature of the cylinder in our dyno room. Cylinder pressure, and subsequent flow rates through a given orifice, vary dramatically with temperature. If you use our nozzle sizes, and the cylinder temperature increases to 100 degrees F, *your engine will not survive!* A remote cylinder pressure gauge is highly recommended.

3. There's nothing wrong with a moderate load of N2O (20-30 CBHP), but remember that when engine components are continually stressed beyond their design limits, those little metal molecules will eventually get tired of holding hands.

STOCK ENGINE BASELINE
Data for 29.92 inches Hg. 60 F dry air.
TEST: 200 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .711
VAPOR PRESSURE: .15
BAROMETRIC PRESSURE: 29.89

RPM	CBT	CBHP	FUEL	BSFC	CAT
6500	52.4	64.9	38.7	.58	24
6750	59.7	76.7	51.2	.65	25
7000	63.5	84.6	59.5	.68	24
7250	62.9	86.8	59.6	.66	24
7500	63.0	90.0	65.6	.70	24
7750	59.8	88.2	68.6	.75	23
8000	40.9	62.3	62.5	.97	23

EXERCISE IN EXCESS

CONTINUED FROM PAGE 6

N2O .022 GAS .025"
Data for 29.92 inches Hg. 60 F dry air.
TEST: 300 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .711
VAPOR PRESSURE: .15
BAROMETRIC PRESSURE: 29.88

RPM	CBT	CBHP	FUEL	BSFC	CAT
6500	87.9	108.8	77.8	.69	24
6750	87.1	111.9	68.3	.59	24
7000	87.4	116.5	73.0	.61	23
7250	87.9	121.3	82.3	.66	23
7500	87.7	125.2	84.0	.65	23
7750	86.0	126.9	83.3	.63	23
8000	82.0	124.9	76.8	.59	24
8250	56.6	88.9	76.7	.83	24

N2O .025 GAS .028"
Data for 29.92 inches Hg. 60 F dry air.
TEST: 300 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .711
VAPOR PRESSURE: .15
BAROMETRIC PRESSURE: 29.89

RPM	CBT	CBHP	FUEL	BSFC	CAT
6750	90.9	116.8	82.6	.70	43
7000	91.6	122.1	87.6	.71	43
7250	92.0	127.0	90.3	.70	43
7500	91.5	130.7	94.0	.71	43
7750	90.5	133.5	93.6	.69	41
8000	88.4	127.9	88.9	.69	42
8250	81.4	127.9	88.9	.69	42

N2O .028 GAS .034"
Data for 29.92 inches Hg. 60 F dry air.
TEST: 300 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .711
VAPOR PRESSURE: .15
BAROMETRIC PRESSURE: 29.89

RPM	CBT	CBHP	FUEL	BSFC	CAT
6750	96.2	123.6	78.1	.62	44
7000	96.6	128.8	89.4	.69	44
7250	95.3	131.6	95.6	.72	44
7500	93.4	133.4	96.3	.71	45
7750	92.0	135.8	102.6	.75	44
8000	90.0	137.1	98.0	.71	44
8250	77.4	121.6	104.3	.85	45

N2O .030 GAS .034"
Data for 29.92 inches Hg. 60 F dry air.
TEST: 300 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .711
VAPOR PRESSURE: .15
BAROMETRIC PRESSURE: 29.88

RPM	CBT	CBHP	FUEL	BSFC	CAT
6750	97.8	125.7	78.9	.62	39
7000	97.1	129.4	91.7	.70	39
7250	95.7	132.1	93.3	.70	39
7500	94.8	135.4	96.0	.70	40
7750	92.9	137.1	101.1	.73	40
8000	91.3	139.1	96.8	.69	41
8250	83.4	131.0	107.5	.81	40

N2O .032 GAS .034"
Data for 29.92 inches Hg. 60 F dry air.
TEST: 300 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .711
VAPOR PRESSURE: .15
BAROMETRIC PRESSURE: 29.88

RPM	CBT	CBHP	FUEL	BSFC	CAT
6750	100.3	128.9	83.0	.64	43
7000	99.8	133.0	90.4	.67	43
7250	99.2	136.9	93.0	.67	45
7500	98.6	140.8	99.5	.70	44
7750	97.0	143.1	100.4	.69	44
8000	93.8	142.9	97.7	.68	44
8250	87.1	136.8	98.4	.71	43

N2O .034 GAS .036"
Data for 29.92 inches Hg. 60 F dry air.
TEST: 300 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .711
VAPOR PRESSURE: .15
BAROMETRIC PRESSURE: 29.88

RPM	CBT	CBHP	FUEL	BSFC	CAT
6750	104.5	134.3	74.1	.54	41
7000	104.1	138.7	87.1	.62	41
7250	103.9	143.4	94.2	.65	42
7500	104.5	149.2	98.1	.65	42
7750	104.6	154.4	101.0	.65	43
8000	101.1	154.0	99.6	.64	43
8250	66.8	104.9	107.2	1.01	42

N2O .036 GAS .038"
Data for 29.92 inches Hg. 60 F dry air.
TEST: 300 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .711
VAPOR PRESSURE: .15
BAROMETRIC PRESSURE: 29.87

RPM	CBT	CBHP	FUEL	BSFC	CAT
6750	108.4	139.3	79.5	.56	42
7000	107.6	143.4	89.8	.62	41
7250	109.2	150.7	96.5	.63	41
7500	109.2	155.9	103.3	.65	41
7750	108.1	159.5	102.4	.63	41
8000	106.1	161.6	101.7	.62	42
8250	91.9	144.4	108.9	.74	41

N2O .040 GAS .042"
Data for 29.92 inches Hg. 60 F dry air.

TEST: 300 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .711
VAPOR PRESSURE: .15
BAROMETRIC PRESSURE: 29.87

RPM	CBT	CBHP	FUEL	BSFC	CAT
6750	107.7	138.4	82.2	.58	34
7000	110.3	147.0	91.8	.61	34
7250	110.1	152.0	97.0	.63	34
7500	111.7	159.5	102.7	.63	35
7750	110.3	162.8	106.5	.64	35
8000	109.6	166.9	104.6	.61	35
8250	104.2	163.7	107.0	.64	34

EXERCISE IN EXCESS

CONTINUED FROM PAGE 7

N2O .042 GAS .042"
Data for 29.92 inches Hg. 60 F dry air.

TEST: 300 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .711
VAPOR PRESSURE: .15
BAROMETRIC PRESSURE: 29.87

RPM	CBT	CBHP	FUEL	BSFC	CAT
6750	107.7	138.4	82.2	.58	34
7000	110.3	147.0	91.8	.61	34
7250	110.1	152.0	97.0	.63	34
7500	111.7	159.5	102.7	.63	35
7750	110.3	162.8	106.5	.64	35
8000	109.6	166.9	104.6	.61	35
8250	104.2	163.7	107.0	.64	34

I have had several years of dyno and field experience with a N2O injected trail sled (a 100 CBHP Kawasaki Invader in the late 70's, when 100 CBHP was a lot). The following pros and cons are offered.

CON: High octane gasoline should be used with all but the meekest loads

PRO: Extremely good cost/ horsepower ratio.

CON: A different clutch setup is necessary for correct operation when N2O is utilized.

PRO: Sled retains basically stock trail performance and resale value.

CON: A N2O injected sled feels slow when not "on the button".

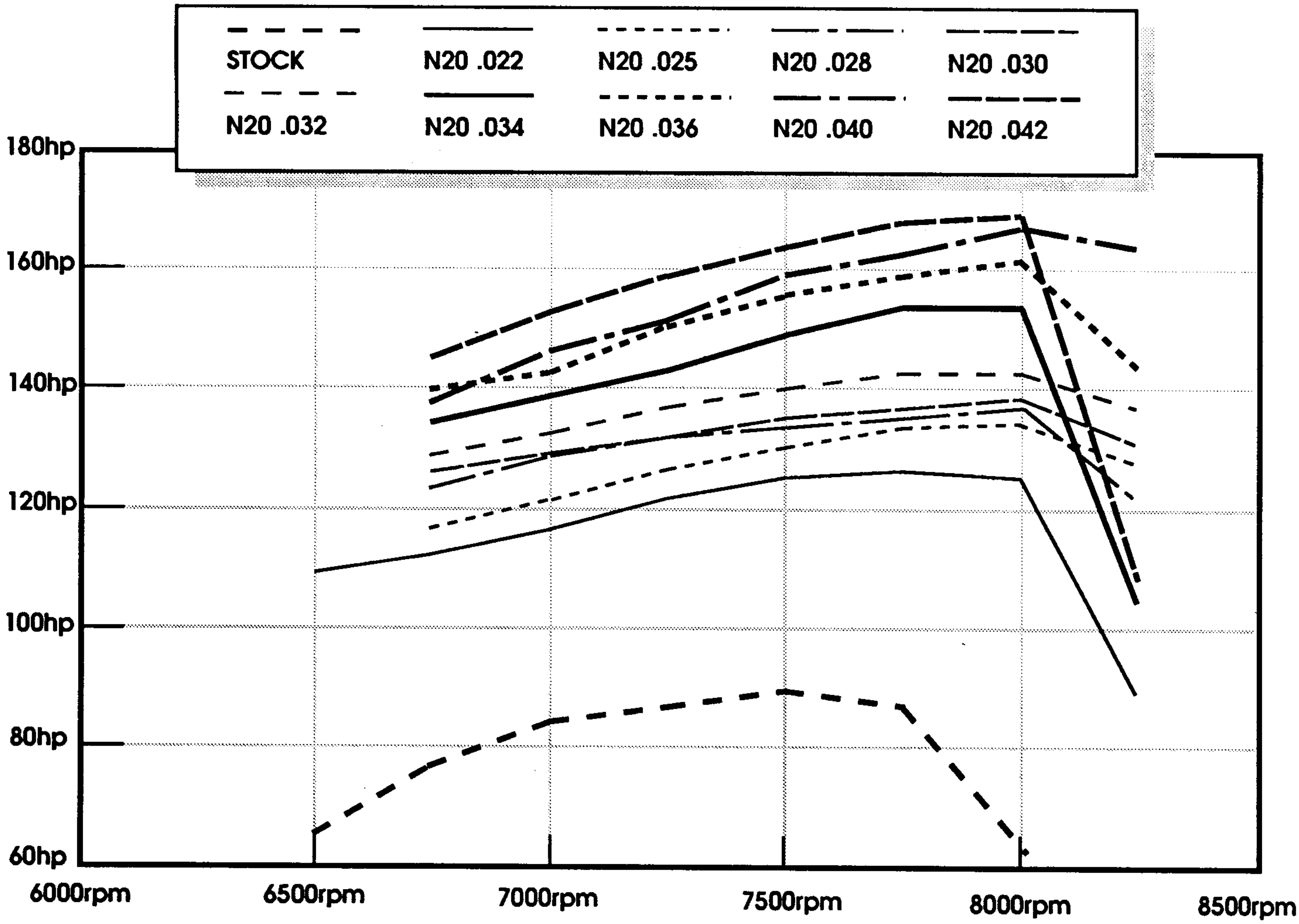
PRO: Easy kit installation and tuning.

CON: Additional performance is temporary, limited by the the size of the N2O cylinder. A two lb. cylinder (refill cost @$8.00) might give you thirty seconds of enjoyment with a thirty HP load.

PRO: N2O adds horsepower everywhere in the powerband.

CON: N2O high pressure cylinders can be deadly bombs if not properly cared for. Deep scratches or nicks, and excessive heat must be avoided. Every year, people are maimed or killed while transfilling cylinders that have been rendered unsafe by stress risers created by deep nicks or scratches, corrosion, or loss of heat treat in the metal. Aluminum can lose its heat treat with as little as 500 degree temperature. I shudder when I hear of people using 3000 degree torches to raise the pressure of cold N2O cylinders.

PRO: N2O high pressure cylinders are extremely safe when properly mounted and maintained, and hydrostatically tested every five years.



PIPE SHOOTOUT #10

FORMULA III SPEC MACH I

PRESENT DURING TEST:
JIM CZEKALA, LARRY AUDETTE,
BREC NORTON & JERRY BASSET

Larry Audette of the Crank Shop in Essex Junction, Vermont (802-878-3615) brought us an FIII spec (standard bore and stroke) engine upon which to compare the currently available aftermarket twin pipes. This is basically a full mod engine, designed for racing on high octane fuel.

The rotary valve timing was set at 140-85, the exhaust ports were 60mm wide and raised two mm from stock, and the transfer ports were raised one mm. The uncorrected compression ratio was 16-1, and ignition timing was set at .085.

We used the same aftermarket twin pipes that we tested earlier on our stock Mach 1 engines, as well as a set of unsilenced SkiDoo Factory Race pipes.

The Crank Shop manufactures custom slides designed to accommodate overboring 44mm Mikuni carbs to 48mm. Larry's 48mm carbs were used, and the jet sizes shown gave the highest horsepower and lowest BSFC that we could obtain with each particular pipe set. **NOTE: this should be considered a drag spec for our Carb Air Temp. Also, keep in mind that the Mikuni Pocket Tuner does not correlate well with the 48mm carbs. They need to be calibrated by the use of an instrumented dynamometer, or by reading pistons and plugs in the field.**

To show the actual power advantage of the larger carbs, we included the best dyno test results we were able to achieve with standard 46mm Mikuni carbs when used with the SkiDoo factory FIII pipes.

FIII PIPES 46mm CARBS 440-400mj
Data for 29.92 inches Hg. 60 F dry air.
TEST: 200 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .700
VAPOR PRESSURE: .30
BAROMETRIC PRESSURE: 30.08

RPM	CBT	CBHP	FUEL	BSFC	CAT
7250	46.4	64.1	38.4	.60	61
7500	49.8	71.1	46.4	.66	60
7750	54.4	80.3	52.1	.65	60
8000	56.8	86.5	54.7	.64	61
8250	61.7	96.9	56.3	.58	60
8500	64.2	103.9	57.8	.56	60
8750	68.6	114.3	68.5	.60	59
9000	74.7	128.0	71.4	.56	59
9250	76.2	134.2	73.0	.55	59
9500	75.6	136.7	73.7	.54	60

FIII PIPES 48mm CARBS 900-800mj.
Data for 29.92 inches Hg. 60 F dry air.
TEST: 200 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .700
VAPOR PRESSURE: .30
BAROMETRIC PRESSURE: 30.07

RPM	CBT	CBHP	FUEL	BSFC	CAT
7250	48.4	66.8	40.4	.61	62
7500	50.8	72.5	45.2	.63	63
7750	57.0	84.1	52.9	.64	64
8000	57.5	87.6	55.2	.64	63
8250	59.7	93.8	66.3	.71	63
8500	65.6	106.2	66.5	.63	63
8750	72.0	120.0	62.5	.52	57
9000	76.0	130.2	65.0	.50	60
9250	76.9	135.4	68.3	.51	62
9500	76.3	138.0	72.1	.53	64
9750	69.7	129.4	75.8	.59	65

FAST PIPES 48mm CARBS 540-480mj.
Data for 29.92 inches Hg. 60 F dry air.
TEST: 200 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .700
VAPOR PRESSURE: .30
BAROMETRIC PRESSURE: 30.08

RPM	CBT	CBHP	FUEL	BSFC	CAT
7000	55.7	74.2	42.1	.57	67
7250	58.2	80.3	43.6	.55	67
7500	68.3	97.5	50.7	.53	68
7750	75.5	111.4	59.1	.54	67
8000	77.8	118.5	64.9	.55	68
8250	77.0	121.0	66.6	.56	67
8500	72.5	117.3	64.9	.56	67

PIPE SHOOTOUT

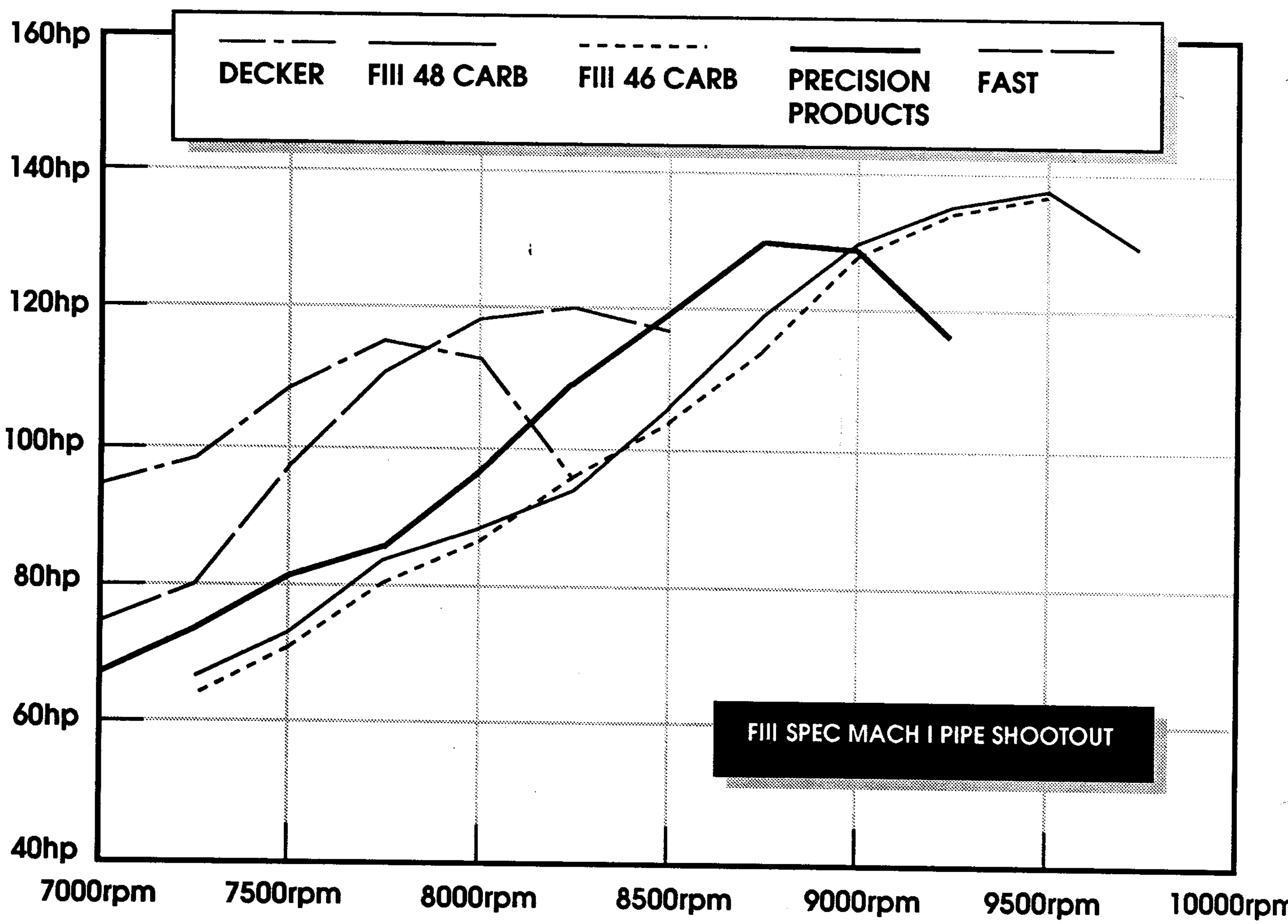
CONTINUED FROM PAGE 9

DECKER PIPES 48mm CARBS 480-440mj.
Data for 29.92 inches Hg. 60 F dry air.
TEST: 200 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .700
VAPOR PRESSURE: .30
BAROMETRIC PRESSURE: 30.08

RPM	CBT	CBHP	FUEL	BSFC	CAT
6250	61.8	73.5	51.8	.71	66
6500	63.8	79.0	52.7	.67	67
6750	68.3	87.8	53.5	.61	65
7000	70.4	93.8	58.1	.62	67
7250	71.5	98.7	61.9	.63	66
7500	76.3	109.0	65.4	.60	66
7750	78.0	115.1	67.6	.59	67
8000	74.0	112.7	71.6	.64	67
8250	60.9	95.7	69.9	.73	66

PRECISION PRODUCTS PIPES 48mm CARBS 800-740 mj.
Data for 29.92 inches Hg. 60 F dry air.
TEST: 200 RPM/Sec Accel.
FUEL SPECIFIC GRAVITY: .700
VAPOR PRESSURE: .30
BAROMETRIC PRESSURE: 30.08

RPM	CBT	CBHP	FUEL	BSFC	CAT
6750	46.2	59.4	40.8	.69	57
7000	50.9	67.8	43.8	.65	57
7250	53.1	73.3	47.5	.65	56
7500	57.1	81.5	58.2	.71	55
7750	57.7	85.1	59.5	.70	56
8000	63.6	96.9	65.2	.67	57
8250	69.8	109.6	70.9	.65	57
8500	74.2	120.1	65.8	.55	56
8750	77.9	129.8	62.6	.48	56
9000	75.3	129.0	66.9	.52	57
9250	66.0	116.2	70.5	.61	57



FEEDBACK JIM CZEKALA

NEW TECH LINE: 716-344-1312
As of January 1990, we discontinued our 800 number, and replaced it with a new Subscriber's Only Tech Line. I will try to be available for tech consultation *most* Fridays and *some* Thursdays. We schedule private testing Monday trough Wednesday, and I'm unfortunately not available during those sessions.

Debbie and Derek normally answer the phone, and can assist in basic data clarification. However, they aren't involved in the actual dyno or field testing--detailed technical questions need to be addressed by me.

WHICH OIL IS BEST?
One commonly asked question is whether we have seen power differences when testing different brands, types, and ratios of oils. Our oil testing to date has been somewhat inconclusive. When we correctly compensate for differences in actual fuel flow caused by different premix ratios and grades of oil, power differences are minimal. Large doses of premixed oil are often accompanied by slight horsepower gains, which can usually be attributed to lower fuel flow caused by the higher viscosity of the premix. The same horsepower gain can be accomplished by installing smaller jets.

The down side of using lots of oil is the reduction of the precious octane of the gasoline. That's one of the reasons why I prefer using small quantities of synthetic oil in the pre-mix for our modified Polaris engine. I use Amsoil 100-1 synthetic, usually mixed at, maybe 70-1 (for psychological reasons). I'm sure there are other good synthetics out there, but I've never tried them.

I've also heard (but never verified) that there are two different base stock injection oils that coagulate when mixed. I believe that your best bet is to stick with your sled manufacturer's particular injection oil.

WHICH SPARK PLUGS ARE BEST?
Our dyno testing to date has not revealed any horsepower differences between different brands of plugs, as long as the heat range is correct. There is one exception. We tried a set of surface gap style plugs (like we used to run in Merc outboards) in the Merc 400 ST tested in Vol.1 #1 last year, and lost about two horsepower compared to the B9ES plugs we had been using.

KING TORQUE
Larry Audette of the Crank Shop reminded me that one of his twin rotary valve Mach 1 870cc triples made over 116 corrected foot-pounds of torque on our dyno last year, on gasoline. I had mistakenly told Denny Johnson that his N2O injected Mach 1's 114.5 corrected foot-pounds was the highest torque of any single snowmobile engine we had tested to date--he subsequently used that statement in a few ads that he placed in Snow Week.

To set the record straight, that monster Crank Shop Mach 1 1/2 is our current "King of Torque". Denny probably wouldn't be thrilled with the title "Queen of Torque", so how about "First Runner-Up King of Torque"?

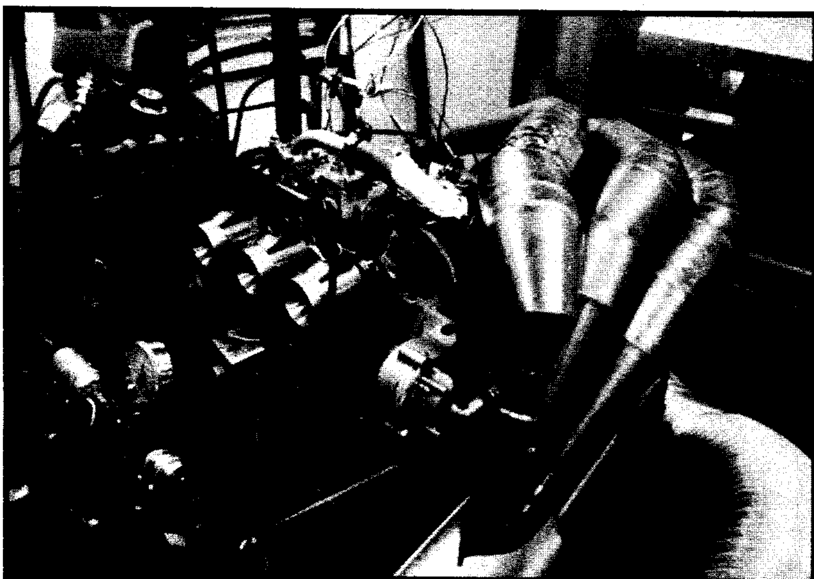
NEW DYNOTECH PROJECT SLED
EFI 854 CC EXCITER
At press time, we had just completed our newest project sled. We sent a new electric start Yamaha Exciter to nearby Bender Racing, where it was magically tran$formed into a three cylinder "Avalanche" (1 and 1/2 Exciter engines welded together) low compression trail sled. We opted for the Terminator porting and pipes, which would easily give us 160+ CBHP at 8500 RPM on pump gas.

At the same time, Injection Research Specialists, Inc. (719-574-1473), of Colorado Springs, CO., has for the first time gone public with their aftermarket Electronic Fuel Injection (see Kevin Cameron's TDC Vol.1 #5). They have spent four years and several million dollars "perfecting" a bolt-on, totally programmable EFI unit for snowmobile engines. Their extensive research and development includes thousands of hours of dyno testing and thousands of miles of field testing, from sea level to 13,000 ft.

Totally confident that their EFI system was ready for public scrutiny, IRS agreed to use our DynoTech project sled as their first public offering. After having applied their EFI to many production engines (including most of the top performance 1990 and 1991 Yamaha, Polaris, and Arctic Cat engines), our Bender Avalanche three cylinder Exciter was their first adventure into an ultra high performance application.

FEEDBACK

CONTINUED FROM PAGE 11



OUR BENDER AVALANCHE 854 BEING MAPPED ON THE IRS DYNO IN COLORADO

In late December, I traveled to IRS in Colorado Springs to have their EFI installed on my 854 Exciter engine and mapped on their dyno. IRS uses a Schenk eddycurrent dynamometer in conjunction with the latest SuperFlow data gathering computer systems. All of their fuel mapping is done in a non-transitional, steady state.

After our 854 Exciter engine was set up on the IRS dyno, the EFI unit was installed. For this application, 48mm throttle bodies were fitted.

"Mapping" the fuel flow of the IRS EFI for a particular engine/port/pipe combo involves a simple multi-step procedure. There are 16 different throttle positions on the X axis, and 16 different RPM levels on the Y axis, for a total of 256 data points which must be determined by the dyno operator. The areas between the data points are interpolated by the IRS on-board computer.

This basic "Map" is measured by the computer in relationship to the particular air density present during the operation of the engine. The computer thereafter takes into consideration Barometric Pressure and Carburetor Air Temperature when determining and allocating the proper amount of fuel flow.

The basic mapping procedure is as follows: the throttle is held at a particular position while the engine is held by the dyno steady-state at a certain RPM level. The actual fuel flow is determined by the position of an IRS "steam wheel", which is a rheostat knob mounted on the dyno console. By slowly rotating the steam wheel from rich to lean, the best possible safe fuel flow is determined and entered manually into the computer.

This is a fairly long and tedious procedure (typically three hours on the dyno, while the engine runs at steady-state), but when it's done, it's done.

After completing the IRS map on our 854 Exciter engine at 5000 ft. altitude, 75 degree F. CAT, the IRS Schenk dyno registered an observed horsepower of 127 (160+ CBHP), 80 LB/HR fuel flow, @.62 BSFC. That looked great and safe to me, but what about when we got back to our near sea-level C&H Dyno Service test facility, where we normally enjoy 30 inches of mercury barometric pressure? Colorado Springs is at 5000 ft altitude and is thereby cursed with a mere 24 inches of mercury barometric pressure. Could the "black box" possibly realize that we were back in "good air"?

With a certain amount of disguised trepidation (and actual relief), I crated up our three cylinder Exciter engine and new EFI unit for shipment back to Western New York.

That same day, Bender Racing personnel installed the 854 Avalanche engine and IRS EFI unit in our chassis, and it was ready for our sea level Dyno analysis.

Back on the C&H Dyno, the air temperature was in the mid thirties. The barometer read 29.80 in. hg.. The EFI was flawless on warmup; automatic fuel enrichment gradually dropped out at 75 degree F. water temperature.

After a thorough heat soak, we accelerated the engine to an observed 169 horsepower (160+ CBHP), 109 LB/HR fuel flow, at a safe .64 BSFC! That tiny little "black box" somehow knew that we had spirited it down to sea level, and had made all of the correct adjustments!

The following day, the barometer had risen to 30.30 in.hg., due to a changing weather front, and the fuel flow automatically increased to 111 LB/HR, just like magic.

FEEDBACK

CONTINUED FROM PAGE 12

We are very excited about this potential revolution in snowmobile engine technology. During the tail end of the season, we'll be pounding this engine on pump gas, from sea level to 2000 ft, from -20 degrees F to +40. And my hands won't reek of gasoline from changing jets.

FOR SALE 136 HP DYNOTECH PROJECT SLED
Yamaha Exciter, powered by a 136 CBHP Polaris 650 engine. Ported by Bender Racing, Swaintech TBC pistons, 39.2 mikuni carbs w/Dial-a-Jets, cold air induction, Polaris clutches, Polaris brake, Polaris track w/carbide studs & Bender Stud-Mates, Polaris tach, extra quiet PSI stage 2 pipes, Bender wide front end, suspension, 112mph on radar. 500 trail miles. $6500. Buyer must provide Dial-a-jet and SwainTech TBC feedback.

MORE PIPE SHOOTOUTS
Very shortly we'll be completing our stock and modified Wildcat Pipe Shootouts. PSI has slightly changed their pipe design for 1990, Starting Line Products has a new set that uses either the stock canister or individual silencers, and Decker has come out with a set of Wildcat twins.

For you V-Max aficionados (still a current model in Canada), we'll soon be testing the stock and update ported V-Max with whatever aftermarket pipes are available. Also, we'll test the stock pipes with a factory recommended cut out of the header pipe and center section for mod engines.

Also, we've got a selection of single pipes for the Arctic Cat Cougar. That will also be coming up shortly.

MODIFIED PHAZER UPDATE (THIS ISSUE)
Consulting Editor Rod champagne has developed a more radical port configuration for the Phazer (including raised exhaust and transfer ports), to see if we can generate more top end power. We'll be testing those cylinders later this year, and will publish the results.

IMBALANCED THINKING

THE CELLAR DWELLER KEVIN CAMERON

Each time a fast moving piston stops and reverses at TDC or BDC, it tends to drag the whole engine with it. This is because the energy of the moving piston cannot be destroyed; it is simply exchanged between the parts--from piston to crankcase. These piston reversal impulses--delivered at the rate of two per crank revolution--are what is called primary reciprocating imbalance.

Primary imbalance takes place along the cylinder centerline and, as such, cannot be counterbalanced by a counterweight moving in a circle--as on the crankshaft.

A crank mounted counterweight produces a rotating force that causes the entire engine to orbit around some point in space. As you can see, the piston makes the engine jump up and down along its cylinder centerline, while a crank counterweight makes it orbit around a point in space; these two kinds of imbalance cannot be added to produce zero motion. Therefore the primary imbalance of a single-cylinder engine cannot be balanced by putting counterweights on the crankshaft.

Now we need to define rotating imbalance, which is anything that adds weight to one side of a rotating part without putting an equal weight, at an equal distance from center, on the other side. Fotunately, rotating imbalance can be balanced out perfectly--just as a teeter-totter is balanced. In an engine, rotating imbalance is made up of the crankpin, the weight of the con-rod's big end, and the big-end bearing. In any engine, it is customary to balance 100% of the rotating imbalance, so there is zero vibration from this source.

Assume we have balanced 100% of the rotating imbalance, but we still have primary, reciprocating imbalance to deal with. This consists of the

IMBALANCED THINKING

Continued from page 13

weight of the piston, its ringpack, the wristpin and its clips, wristpin bearing, and the small end weight of the connecting rod--all jerking the engine up and down as it starts and stops thousands of times a minute. Let us arbitrarily call this amount of primary imbalance one hundred imbalance units.

Now let us add to the side of the crank 180 degrees from the crankpin a counterweight whose weight is 10% of the primary reciprocating imbalance. When we run the engine, we find to our delight that now the engine only jumps up and down with 90 units of imbalance. The debit side of this operation is that now the engine is jumping forwards and backwards, at 90 degrees to the cylinder centerline, at ten units of imbalance. If we increase our counterweight to 20% of the recip imbalance, we find the engine jumps up and down at 80 units of imbalance, which is progress, but now it's jumping forwards and back at 20 units.

What is happening here? We are shifting imbalance out of the vertical, and into the horizontal direction. Indeed, if we balance at 100% of reciprocating weight, the engine stops jumping up and down altogether, but now jumps forward and back at 100 units of imbalance. Why? The reason is that a rotating imbalance can be viewed as the sum of two reciprocating imbalances at right angles to each other. By deliberately creating a rotating imbalance equal to 100% of the reciprocating imbalance, its vertical component exactly cancels the the piston's reciprocating imbalance (because we put the counterweight at 180 degrees to the crankpin). However, nothing is canceling the horizontal component of our 100% rotating imbalance, so the engine jumps forward and back at 100 units of imbalance.

As you can see, the best deal we can get out of this situation is to balance at about 50% Of reciprocating weight, for this cuts the vertical jumping in half, while creating an equal forward-and-back vibration. Doing this reduces the reciprocating loads on the crankshaft main bearings by half, so it is mechanically desirable as well. This is as close to "balanced" as a single-cylinder engine can get, using only crank-mounted counterweights.

Sometimes there are good reasons for not balancing an engine at 50% of recip weight, however. On a motorcycle, for instance, the rider will feel up-and-down vibration much more acutely than he will feel forwards-and-back vibration. Therefore single-cylinder and 360-degree twin motorcycle engines are balanced at very high percentages--typically 75-80%. This shifts the vibration from vertical (annoying) to horizontal (not so noticeable).

Lets go over the balancing procedure again; the rotating imbalance--crankpin, rod big-end, and big end bearing--is first balanced at 100%, meaning that a counterweight of that total amount is added to the crank at 180 degrees to the crankpin. Next, the reciprocating weight is added up--that of the con-rod small end, piston, wristpin, and ring pack--and a percentage of this total weight is then added as a crank counterweight, also located at 180 degrees from the crankpin. In most cases, the best percentage to use is 50 %, as this cuts main bearing loads in half, but as noted above, there may be reasons for balancing at other percentages.

STRUCTURAL RESONANCE

The structure on which the engine is mounted is always flexible to some degree, and so can act as a spring. The system consisting of the vibrating mass of the engine, coupled to this "spring", has certain vibratory natural frequencies, at which the engine/chassis motion will greatly increase--just as a pendulum swings furthest when you tap it in step with its natural swing frequency. Because of this resonance phenomenon, at certain RPM your engine and sled will have vibration peaks. These are usually dealt with by use of energy-absorbing rubber engine mounts, by changing the stiffness of the chassis, or by re-balancing the engine to shift its vibration out of the direction that is exciting the chassis.

So far we have dealt only with the problems of a single-cylinder engine, or of a parallel twin whose pistons go up and down together. Now we have to consider the very common parallel twin with crankpins at 180 degrees. On these engines, the up-force from one piston is largely cancelled by down-force from the other, but this doesn't solve much because the cylinder centerlines are offset from each other. Therefore, instead of lying still in the chassis, this type of engine tends to rock from side to side. As the cylinder centerlines are moved closer together, this rocking decreases and vice versa. For balance reasons, the designer wants to make the engine very narrow, but to accomodate generous transfer ports, he wants to make it wider. Usually, the transfer ports win this battle, and so twins have a vigorous 'rocking couple", as this type of vibration is called.

IMBALANCED THINKING

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When we balance a twin like this at 100% of rotating imbalance and 50% of reciprocating imbalance, as we did in the best case for a single, we find that instead of simply rocking from side to side, the crankshaft now describes what I call "kayak-paddle motion", which means that the center of the crank simply rotates, but its ends describe circles in space–like the blades of a double bladed kayak paddle in use.

Again, like the single-cylinder case, this balancing at 50% of recip weight is the best we can do, assuming the designer has put his cylinder centerlines as close together as they can be. As with the single, balancing at 50% cuts main bearing loads in half, as compared with an engine balanced at zero percent.

Next we come to the three-cylinder in-line configuration, with crankpins set at 120 degree intervals. The textbooks tell us that these engines are self-balancing with respect to primary imbalance; as much piston mass is being accelerated upward as is being accelerated downward, and it all neatly cancels. Yes, but the rocking couple remains, and it is a particularly violent one because of the great length the cranks of these engines usually have. For this reason the designers employ all sorts of clever techniques to make these engines narrower--offsetting the cylinders, twisting them, and so on--all to make the engine shorter, thereby reducing the rocking motion.

When two three cylinder engines are joined end-to-end in a common crankcase, the rocking couples cancel, leaving us with an engine that is indeed inherently smooth, even without any crank counterweighting. However, out of compassion for those main bearings, all kinds of engines used in heavy service will typically be balanced at about 50%, as in the simple case of a single.

Often, however, manufacturers balance at very low percentages of recip weight and just let their engines pound and hammer more than they need to. Why do they do it? Well, it's expensive to drill big holes in the flywheels. Although piston-port engines thrive on large crankcase volumes, some designers don't like to balance by drilling holes because of the volume this adds to the case. The alternatives are to weld coverplates over the drilled holes, fill them with some shaky mixture like cork/epoxy, or to put the holes near 180 degrees to the crankpin and fill them with heavier-than-steel material–either lead (which is bad in high RPM engines because the soft material slowly squishes out towards the OD of the flywheel) or tungsten (which is expensive and hard to cut and shape besides). Therefore a lot of engines are balanced at 35% or less, and so shake a lot more than they need to.

Should you ship off all your parts to the balancer immediately, if not sooner? Consider carefully. In order to balance the crank, the balancing shop will ask that the crank be sent to them assembled, but without rods, big-end bearings, or sidewashers on the crankpins. This is so bob-weights of the correct mass can be attached to the pins and the crank can be spun in the balancing machine. Once the size and location of the changes to the crank (holes, heavy filler, etc.) have been determined, the crank can be taken apart and reassembled with its rods and bearings. All this is a lot of work. Every time a crank is pressed apart and pulled together again, some of the strength in its press-fits is lost. In effect, you are paying for two crank rebuilds plus the balancing, to get a smoother running crank that has less grip in its press joints. It may be worthwhile if you have a terrible balance problem--tearing out of the chassis, putting the riders bum to sleep at 6200 RPM--or it may be better just to suffer in silence.

There is another type of vibration to consider--torsional vibration. When the engine fires, combustion energy pushes on the piston, which accelerates the crankshaft suddenly. As the piston comes around on exhaust, transfer and compression, it has nothing to push it but the energy stored in its crank, so the crank slows back down. Then at the next firing, the crank recieves another powerful twisting force to speed it up again. Thus, instantaneous crank RPM varies constantly. Normally something in the drive system absorbs this--slippage or elasticity in the drive belt, for instance.

However, there can be trouble when there are other large masses attached to the crank, such as one of the new, external-magnet ignition rotors. Now we have the massive crank with its solid steel flywheels, connected by a shaft to a similarly massive ignition/generator rotor. In effect, we have two masses joined by a torsion spring--the steel shaft. The danger is that, at some RPM, the frequency of the firing impulses will come into step with the natural frequency of these two masses connected by this torsion spring. On older engines, the shafts often broke as a result of rapid accumu-

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lation of fatigue cycles in the shaft. Modern designs usually have short, massive shafts, so this moves the point of vulnerability to the taper joint between the rotor and the shaft. Unless the rotor is very firmly seated on the shaft, and fits it extremely well, torsional impulses can cause a slight back-and-forth slippage in the joint. The evidence you may see is in the form of rust-colored powder (the color is no accident--it is rust--iron oxide) or discoloration on the shaft. This kind of symptom, called fretting, can lead to surface defects large enough to enlarge over time into cracks.

When the rotors are installed at the factory, they are put together clean and dry, then torqued up to a spec that has been found to work. When you pull the rotor and then reinstall it, the cleanliness and torque may be absent. As insurance, I like to lap rotor and shaft together with fine abrasive (600 carbo, for example), then clean thoroughly and assemble. In some cases, people report that Loctite on the taper helps as well.

Another area in which balance affects engine performance is in carburetion. I have watched through transparent floatbowls installed on three-cylinder engine carbs; as engine revs are brought up, the carbs (especially the outer ones) begin to waggle from side-to-side, and the centrifugal force from this causes the fuel to climb the rear walls of the bowls--exactly as though the sled were strongly accelerating forward. In some cases, the fuel moves enough to uncover the mainjet, fuel delivery drops, and the engine may be in big trouble. On a triple, stagger jetting must often be resorted to as a way to compensate for vibration, which affects each of the carbs differently. Usually, the center carb has no problem, while the outer pair require typically 1-3 sizes bigger, if there is a vibration problem.

What can be done about this? First, many sled carb mounts are far too stiff to begin with. There are thinner ones available that change the natural frequency at which the carb vibrates, and they can be tried first. Another idea which has worked for me is to change the mass of the carbs by wrapping tape-a-weight or some similar lead material around the intake bell. This will reduce the frequency of carb/manifold resonance, possibly putting it below your engine's working range. The engine itself may be moving in its mounts excessively, amplifying the motion of the carbs. Another workable solution is to make up a carb unity plate or bar. The plate joins the carbs from the bottom, by fitting up over the floatbowls and being secured with the bowls by extra-length screws. This is a bandsaw and milling machine project. Some carbs have a pair of bosses at the top of the casting, just below where the carb cap screws on. A rod and spacer can be used to join the carbs through these bosses, making them all vibrate as one.

As well as being out of balance, pressed-together crankshafts can also be 'out-of-truth', so that not all bearings are in a straight line. This is especially bad if (1) the out-of-round results in the heavy crank-mounted clutch pulley whipping violently, or (2) you have an old crank-mounted points ignition, whose timing can shift all over the map if that end of the crank is out of round. A factory-fresh crank is trued to less than .001 inch of runout, but a used unit may be out .002-.004 inches at the shaft ends without being much of a problem. My favorite was an old Yamaha 650 sled twin whose clutch was wobbling a quarter inch! It's no surprise if clutch life is short under those conditions, and, even if the crank is true, extravagant engine vibration can quickly age clutch components.

There are fancier solutions to engine imbalance. Two counter-rotating shafts, each carrying a counterweight, can be made to produce a reciprocating imbalance. This is because the forwards-and-back components of the two vibrating shafts cancel, leaving only the up-and-down component. Such an arrangement of counter-rotating balancer shafts is often used to smooth out auto engines, but it involves extra weight that would be out of place on a sled.

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