Volume 3 Number 3 1991

DYNOTECH

THE SNOWMOBILE PERFORMANCE PUBLICATION

PIPE SHOOTOUT #16

1991 MODIFIED POLARIS INDY 650

Present during test: Jim Czekala, Rob Schooping, Dan Cross, Dan McCauley

Owner of sled: Dan McCauley

This 1991 Polaris 650 carbureted "02" engine was modified by Rob Schooping of Hot To Go (HTG) Racing in Grand Island, N.Y. (716-773-6131). The engine was destined for use in heavy mod stock dragracing, where stock carb bodies and quiet pipes are required. It was also going to be trail ridden occasionally on 92 octane pump gas.

Rob got involved with Jim Appolson's FIII oval racing program this past season. With the help of the Polaris factory he came up with these "02" port specs that have been used quite successfully by trail mod and full mod engines.

Very basically, the intake port has been lowered to 102mm, and the exhaust and transfers raised to 28mm and 47mm respectively. With .040" removed from the heads, the uncorrected compression ratio of this engine is 13.5-1. We moved the ignition timing around a bit, and found that stock timing was optimum.

As is always the case, port shapes, sizes and contours are critical to airflow and engine performance. These port dimensions are not all that different from the "01" mod 650 that we tested in V1#3. It's interesting, however, to note how much higher the airflow and torque and horsepower are on the new "02" cylinders. Experienced porting men say that they can duplicate the "02" mod transfers on the old style cylinders, but it's something we've never seen ourselves. To generalize somewhat, the best of the "02" 650 mod engines that we've tuned so far are five to ten horsepower better than the best of the "01" mod engines.

The stock 38mm carbs were bored to 39.2mm. Q2 needle jets and 320 main jets compensated correctly for mid-forty degree F carb air temperatures. A stock gutted airbox was used. This combination yielded A/F ratios around 13-1 and BSFC in the high .50's-low.60's.

Considering the fairly high compression, this may be a good drag spec on 92 octane pump gas at 45 degrees F. Even so, for Dan McCauley's peace of mind we used VP C12 gasoline premixed with Polaris oil.

THE AFTERMARKET PIPES:

For our dyno comparison, we used the same Aaen, Decker, DG, and PSI lake blasters that we tested on the stock '91 650 engine in V3#1. The PSI trail blasters were unavailable, and subsequently not tested on this engine.

We had the new '91 Starting Line Products pipes as well. The new SLP pipes now have individual glasspacked silencers that empty into a single collector, and out the stock bellypan hole. Very similar to the DG pipes, but much quieter.

The new SLP pipes and the PSI Lake Blasters were the least restrictive. They showed higher airflow than the other pipes, and should be more forgiving of lean jetting.

Also included were a set of Rob's HTG quiet pipes, which are of a hand welded cone construction. These have individual silencers which are somewhat "tighter"-- more restrictive than the other pipes. Like the DRE and Aaen pipes, additional exit holes must be added to the bellypan. The HTG pipes are a lower torque, high RPM design and don't work well on stock, or "cleaned up", mildly ported engines.

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PIPE SHOOTOUT CONTINUED

MOD POLARIS 650-*SLP PIPES*--90 dB
39.2 MM CARBS-320 MJ-Q2nj
13.5-1 COMPRESSION RATIO
Data for 29.92 inches Hg, 60 F dry air
Test: 200 RPM/Sec Acceleration
Fuel Specific Gravity: .710
Vapor Pressure: .15 Barometer: 29.93

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
7000	65.2	86.9	56.7	182.3	14.8	.64	39
7250	68.4	94.4	60.2	196.5	15.0	.63	39
7500	70.2	100.2	64.8	207.5	14.7	.63	38
7750	71.5	105.5	66.2	210.8	14.6	.62	38
8000	75.3	114.7	71.6	219.2	14.1	.61	38
8250	78.9	123.9	76.2	225.1	13.6	.60	39
8500	79.9	129.3	79.0	230.8	13.4	.60	39
8750	81.3	135.4	81.5	234.3	13.2	.59	38
9000	81.1	139.0	82.2	236.5	13.2	.58	39
9250	74.4	131.0	84.8	236.9	12.8	.63	38
9500	55.8	100.9	83.7	226.1	12.4	.81	39

MOD POLARIS 650- *PSI LAKE BLASTERS*--96dB
39.5 MM CARBS-320 MJ-Q2nj
13.5-1 COMPRESSION RATIO
Data for 29.92 inches Hg, 60 F dry air
Test: 200 RPM/Sec Acceleration
Fuel Specific Gravity: .710
Vapor Pressure: .15 Barometer: 29.92

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
7250	63.1	87.1	73.5	207.4	13.0	.83	42
7500	64.5	92.1	74.3	210.6	13.0	.79	42
7750	68.3	100.8	72.1	216.1	13.8	.70	41
8000	69.9	106.5	74.9	220.0	13.5	.69	42
8250	72.6	114.0	77.5	223.5	13.2	.67	42
8500	74.3	120.2	80.6	226.3	12.9	.66	42
8750	75.1	125.1	81.3	231.1	13.1	.64	42
9000	76.4	130.9	82.8	232.8	12.9	.62	42
9250	76.4	134.6	83.4	232.4	12.8	.61	43
9500	73.3	132.6	86.5	232.8	12.4	.64	43
9750	61.5	114.2	85.8	227.5	12.2	.74	41

MOD POLARIS 650-*AAEN PIPES*--92 dB
39.2 MM CARBS-320 MJ-Q2nj
13.5-1 COMPRESSION RATIO
Data for 29.92 inches Hg, 60 F dry air
Test: 200 RPM/Sec Acceleration
Fuel Specific Gravity: .710
Vapor Pressure: .15 Barometer: 29.90

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
6750	54.2	69.7	59.6	179.6	13.8	.85	44
7000	56.0	74.6	66.6	193.2	13.3	.88	45
7250	61.4	84.8	68.2	197.5	13.3	.80	44
7500	64.8	92.5	66.8	204.6	14.1	.71	44
7750	68.0	100.3	70.7	204.5	13.3	.70	44
8000	68.1	103.7	70.8	206.6	13.4	.67	44
8250	71.1	111.7	72.8	210.7	13.3	.65	45
8500	73.9	119.6	73.8	217.9	13.6	.61	44
8750	78.3	130.5	78.0	224.7	13.2	.59	43
9000	78.8	135.0	78.1	225.8	13.3	.57	43
9250	77.9	137.2	82.1	225.7	12.6	.59	44
9500	75.6	136.7	82.8	224.4	12.4	.60	45

MOD POLARIS 650 -*DECKER PIPES*--92 dB
39.2 MM CARBS-320 MJ-Q2nj
13.5-1 COMPRESSION RATIO
Data for 29.92 inches Hg, 60 F dry air
Test: 200 RPM/Sec Acceleration
Fuel Specific Gravity: .710
Vapor Pressure: .15 Barometer: 29.90

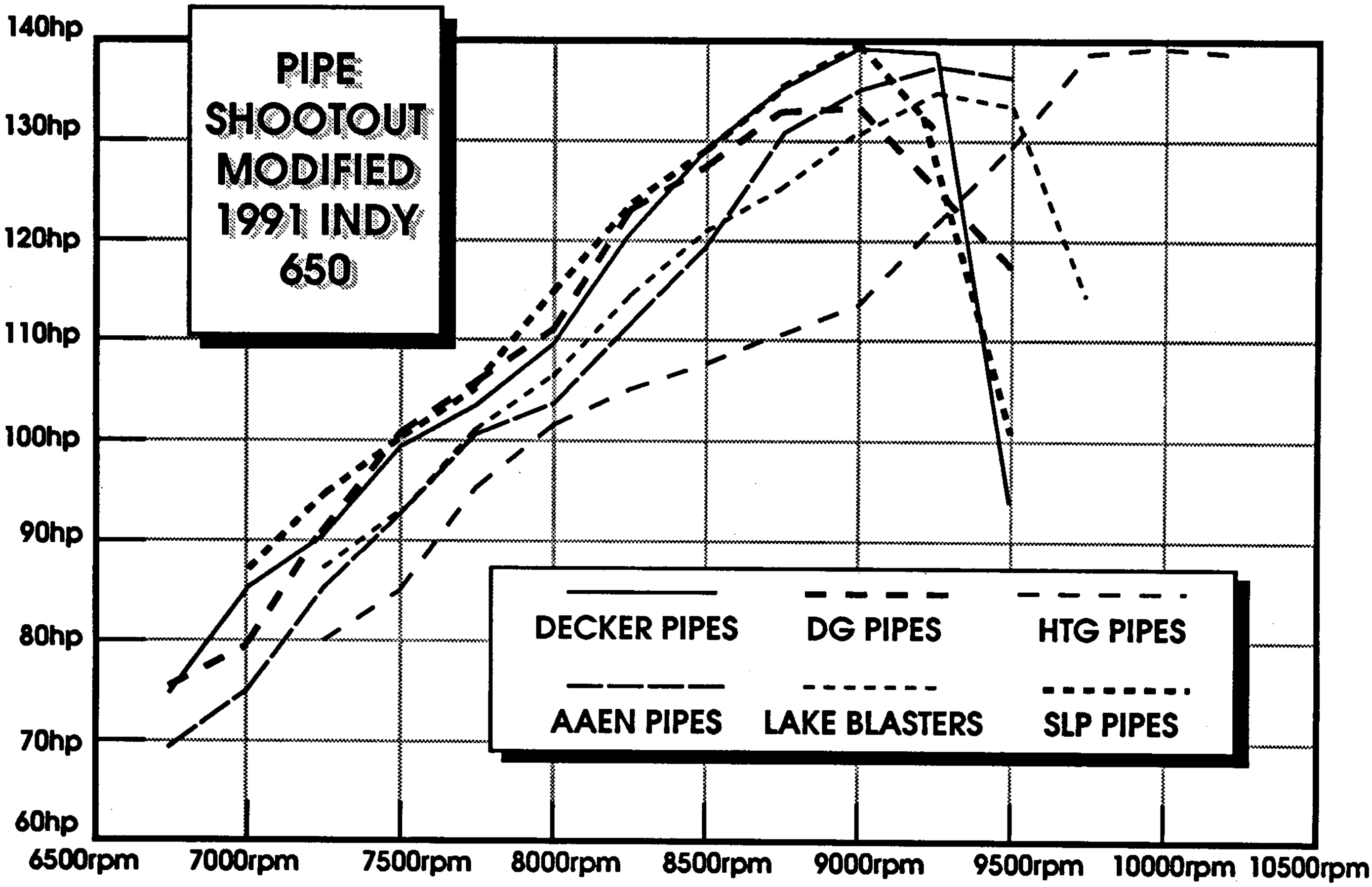
RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
6750	58.1	74.7	64.1	180.7	12.9	.85	46
7000	63.6	84.8	66.4	190.8	13.2	.78	47
7250	65.8	90.8	67.5	195.7	13.3	.74	46
7500	68.8	98.2	68.3	198.2	13.3	.69	46
7750	70.2	103.6	68.2	201.5	13.6	.65	46
8000	71.8	109.4	70.3	203.1	13.3	.64	46
8250	76.6	120.3	73.3	212.7	13.3	.60	46
8500	80.1	129.6	74.4	218.2	13.5	.57	46
8750	81.3	135.4	78.4	223.0	13.1	.57	46
9000	80.9	138.6	81.3	226.1	12.8	.58	46
9250	78.6	138.4	82.5	223.4	12.4	.59	47
9500	51.9	93.9	80.1	208.8	12.0	.84	45

MOD POLARIS 650 -*DG PIPES*--100dB
39.2 MM CARBS-320 MJ-Q2nj
13.5-1 COMPRESSION RATIO
Data for 29.92 inches Hg, 60 F dry air
Test: 200 RPM/Sec Acceleration
Fuel Specific Gravity: .710
Vapor Pressure: .15 Barometer: 29.89

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
6750	58.4	75.1	64.6	186.9	13.3	.86	51
7000	59.9	79.8	68.2	192.5	13.0	.85	52
7250	66.1	91.2	67.6	204.7	13.9	.74	51
7500	70.5	100.7	71.1	208.6	13.5	.70	50
7750	71.7	105.8	71.9	212.5	13.6	.68	49
8000	73.1	111.3	72.8	215.6	13.6	.65	49
8250	78.3	123.0	79.3	223.3	12.9	.64	50
8500	78.3	126.7	81.0	227.1	12.9	.64	49
8750	79.5	132.4	83.0	230.3	12.7	.62	50
9000	77.4	132.6	85.8	231.1	12.4	64	50
9250	66.4	116.9	84.4	227.0	12.4	.72	50

MOD POLARIS 650-*STANDARD LENGTH HTG PIPES*--98dB
39.2 MM CARBS-320 MJ-Q2nj
13.5-1 COMPRESSION RATIO
Data for 29.92 inches Hg, 60 F dry air
Test: 200 RPM/Sec Acceleration
Fuel Specific Gravity: .710
Vapor Pressure: .15 Barometer: 29.91

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
7000	55.9	74.5	53.1	171.2	14.8	.70	36
7250	58.1	80.2	59.6	183.2	14.1	.73	36
7500	63.3	90.4	62.9	197.7	14.4	.68	36
7750	66.0	97.4	63.7	200.6	14.5	.64	36
8000	67.6	103.0	68.1	206.3	13.9	.65	36
8250	66.5	104.5	70.7	208.4	13.5	.66	36
8500	67.4	109.1	73.8	209.1	13.0	.66	36
8750	67.2	112.0	74.9	208.6	12.8	.66	37
9000	68.8	117.9	76.8	209.9	12.5	.64	37
9250	73.2	128.9	76.6	214.4	12.9	.58	36
9500	76.9	139.1	76.9	219.8	13.1	.54	37
9750	75.4	140.0	81.1	222.6	12.6	.57	35
10000	71.1	135.4	80.5	221.8	12.7	.58	36



The following test results show the difference in performance accompanying a change in the HTG pipes' tuned length, with the higher compression and larger carbs. First, Rob shortened the header pipes 1/2" to the full mod length. With the moderate compression, the power peak slid up to 10,000 RPM.

MOD POLARIS 650--*SHORTENED HTG PIPES*--98dB
39.2 MM CARBS-320 MJ-Q2nj
-13.5-1 COMPRESSION RATIO
Data for 29.92 inches Hg, 60 F dry air
Test: 200 RPM/Sec Acceleration
Fuel Specific Gravity: .710
Vapor Pressure: .15 Barometer: 29.89

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
7250	57.5	79.4	67.0	196.1	13.4	.83	39
7500	59.0	84.3	65.4	197.9	13.9	.76	39
7750	64.6	95.3	67.9	200.2	13.5	.70	40
8000	66.4	101.1	67.7	204.9	13.9	.66	41
8250	66.6	104.6	69.7	208.4	13.7	.66	40
8500	66.5	107.6	71.3	208.2	12.4	.65	41
8750	66.1	110.1	74.2	206.9	12.8	.66	41
9000	66.4	113.8	72.5	205.4	13.0	.63	41
9250	68.9	121.3	74.6	206.9	12.7	.60	40
9500	71.6	129.5	76.2	212.2	12.8	.58	40
9750	74.6	138.5	79.3	219.9	12.7	.56	40
10000	73.2	139.4	81.2	223.0	12.6	.57	40
10250	70.8	138.2	81.1	221.2	12.5	.58	40

Next, the compression ratio was raised to 15.5 to 1 by removing .030" (for a total of .070") from the heads. This is all that's necessary to turn this hot trail engine into a competitive mod. It added torque and horsepower throughout the powerband, lowered the BSFC, and dropped the peak back to 9750 RPM. This is 100+ octane compression, even for dragracing.

MOD POLARIS 650 -SHORTENED HTG PIPES--98dB
39.2 MM CARBS-320 MJ-Q2nj
15.5-1 COMPRESSION RATIO
Data for 29.92 inches Hg, 60 F dry air
Test: 200 RPM/Sec Acceleration
Fuel Specific Gravity: .710
Vapor Pressure: .15
Barometer: 29.93

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
7250	61.0	84.2	60.5	192.9	14.6	.71	47
7500	63.8	91.1	64.0	195.0	14.0	.70	47
7750	68.5	101.1	68.1	199.3	13.4	.67	47
8000	70.8	107.8	71.2	203.1	13.1	.65	48
8250	71.2	111.8	74.1	206.9	12.8	.66	47
8500	72.1	116.7	73.8	206.6	12.9	.63	48
8750	72.5	120.8	76.1	205.7	12.4	.62	48
9000	75.9	130.1	75.3	208.6	12.7	.57	47
9250	77.8	137.0	75.9	213.2	12.9	.55	46
9500	78.8	142.5	81.6	219.3	12.3	.57	47
9750	79.5	147.6	80.8	223.5	12.7	.54	47
10000	73.7	140.3	83.9	222.7	12.2	.59	47

What would larger carbs be worth? 44mm Mikunis were fitted with BB0 needle jets and 450 main jets and run open, as they typically would be in the chassis without the airbox. This was worth several horsepower throughout the power band.

MOD POLARIS 650 -SHORTENED HTG PIPES--98dB
***44 MM CARBS*-450 MJ-BB0nj 15.5-1 COMP. RATIO**
Data for 29.92 inches Hg, 60 F dry air
Test: 200 RPM/Sec Acceleration
Fuel Specific Gravity: .710
Vapor Pressure: .15 Barometer: 29.94

RPM	CBT	CBHP	FUEL	BSFC	CAT
7250	62.1	85.7	73.5	.84	84
7500	65.3	93.3	77.3	.81	81
7750	66.0	97.4	76.2	.77	77
8000	68.6	104.5	80.7	.76	76
8250	69.2	108.7	80.4	.73	73
8500	69.9	113.1	76.2	.66	66
8750	72.9	132.5	76.7	.62	62
9000	74.7	128.0	77.4	.59	59
9250	80.4	141.6	75.0	.52	52
9500	81.7	147.8	80.4	.53	53
9750	81.1	150.6	81.8	.53	53
10000	73.9	140.7	83.7	.58	58
10250	61.0	119.0	86.9	.72	72

Dragracing engines sometimes benefit from increasing the backpressure in the pipes. In this case, the standard silencers were removed and short "stinger" pipes were installed. Sometimes we measure the backpressure of the pipes by connecting a pressure hose from the center section to the SuperFlow computer. We can usually find optimum stinger length and size, or muffler restriction this way.

Tight stingers or mufflers can be great for dragracing short distances, but may cause too much internal engine heat for lake or oval racing. The desired backpressure can be obtained either with straight stinger pipes, or correctly sized mufflers/restrictors. It is not necessary to pay a horsepower penalty for running quiet pipes, as long as this is properly addressed.

Note that in this test the fuel flow is lower, indicating less airflow through the engine. The additional heat in the pipes raises the speed of sound of the exhaust gas, which makes the pipes act a bit shorter. Midrange torque and horsepower is off a bit, but at peak and beyond, there is an increase.

MOD POLARIS 650 -SHORTENED HTG PIPES *W/STINGERS*
98dB 44 MM CARBS-450 MJ-BB0nj 15.5-1 COMP. RATIO
Data for 29.92 inches Hg, 60 F dry air
Test: 200 RPM/Sec Acceleration
Fuel Specific Gravity: .710
Vapor Pressure: .15 Barometer: 29.93

RPM	CBT	CBHP	FUEL	BSFC	CAT
7250	60.4	83.4	64.7	.76	40
7500	62.7	89.5	74.8	.82	39
7750	65.4	96.5	76.7	.78	40
8000	67.3	102.5	79.0	.76	39
8250	68.9	108.2	78.7	.71	40
8500	69.7	112.8	76.8	.67	39
8750	70.0	116.6	77.1	.65	39
9000	73.1	125.3	75.3	.59	39
9250	78.3	137.9	75.6	.54	38
9500	81.5	147.4	80.3	.53	38
9750	82.6	153.3	83.2	.53	38
10000	78.9	150.2	84.0	.54	39

I-500 CERTIFICATION

The I-500 is a 500 mile cross country race from Thunder Bay, Ontario, to St. Paul, Minnesota. Last year, the race organizers (and some of the sled manufacturers) were less than thrilled when, after the race, they read our DynoTech test results of each of the sled models. They felt that it was less than fair for there to be a twenty horsepower spread between the entrants.

The rules for this year's I-500 limited the engines to 65 corrected brake horsepower. Race director Floyd Carlson asked us to "certify", in advance, that each of the manufacturers' 65 CBHP engines were indeed 65 CBHP. It was also decided that a five percent "fudge factor" would be allowed.

We elected to obtain test engines randomly from nearby dealers. Compression and squish clearances were checked. Port, crankshaft and ignition timing were all verified. This ensured that the engines were untouched, as shipped to the consumer from the factories.

The only exception was the Prowler Special. At certification time, there were none of these in dealers' hands. Therefore, a complete engine assembly was shipped to us by Arctco. They also included an extra single pipe, which turned out to be one from a 550cc EXT Special, for testing and possible certification.

Our plan was to run each engine on the same gasoline. In this case we used Mobil 92 octane (that's what it said on the pump) unleaded premium. A thorough breakin was performed on each engine.

Jetting the carbs was done only to compensate for the 40-50 degree F carb air temperature; A/F ratios would

CERTIFICATION

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have to be 10-1 or higher to ensure clean firing. Accordingly, we expected the BSFC to be in the mid .70 lb/hphr range.

The engines were tested at steady-state, with readings taken in 250 RPM increments. Each 250 RPM "step test" lasted approximately 60 seconds from start to finish.

THE TEST SESSIONS

YAMAHA SRV

Ron Pearl of Brooks Gravely Yamaha in Rochester, N.Y. (716-424-1660) supplied the SRV engine.

The SRV is a fan cooled 540cc reed valve twin, with a single 44mm Keihin butterfly carb. Intake air is provided by an airbox which draws engine heated underhood air (up to 80 degrees F in winter field conditions). An optional cold air intake kit has been provided by Yamaha in the past, which ducts outside air to the airbox through a louvered panel installed in the fuel tank shroud.

After initial breakin and testing, we installed a 135 main jet. The following test data resulted.

1991 STOCK YAMAHA SRV 135MJ STOCK PIPE

Data for 29.92 inches Hg, 60 F dry air
Test: 250 RPM/Sec Step Test
Fuel Specific Gravity: .745
Vapor Pressure: .20
Barometer: 30.14

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
6000	43.6	49.8	41.5	99.5	11.0	.83	52
6250	45.7	54.4	45.7	105.4	10.6	.83	50
6500	47.8	59.2	45.5	109.8	11.1	.76	49
6750	48.3	62.1	46.3	112.1	11.1	.73	48
7000	48.6	64.8	46.7	113.2	11.1	.71	49
7250	48.3	66.7	46.2	113.4	11.3	.68	49
7500	45.2	64.5	48.1	114.1	10.9	.74	49
7750	42.0	62.0	46.7	111.3	10.9	.74	50
8000	34.0	51.8	45.4	106.4	10.8	.87	50

POLARIS 400 XC

We obtained this engine from the Deerfield Sport Shop in Remsen, N.Y.(315-831-5377).

The 400 XC is actually a 400 engine with its bore enlarged to 440cc. VM38 Mikuni carbs replace the 34mm versions that come on the standard 400.

The single pipe is very similar, if not identical to an Indy 500 pipe. When we tested the engine with a '91 400 pipe, the midrange torque and horsepower were much lower. Peak CBHP was a bit less, and power beyond the peak was lower.

We replaced the stock 280 main jets with 260 mains.

1991 STOCK POLARIS 400XC 260MJ STOCK XC PIPE

Data for 29.92 inches Hg, 60 F dry air
Test: 250 RPM/Sec Step Test
Fuel Specific Gravity: .745
Vapor Pressure: .19
Barometer: 30.26

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
6250	40.4	48.1	37.5	98.0	12.0	.76	41
6500	42.1	52.1	38.9	102.3	12.1	.73	41
6750	43.6	56.0	42.1	104.7	11.4	.73	42
7000	44.3	59.0	43.5	108.4	11.4	.72	42
7250	44.6	61.6	45.7	111.4	11.2	.72	42
7500	45.5	65.0	45.0	113.2	11.6	.67	42
7750	45.2	66.7	45.7	114.4	11.6	.67	41
8000	43.6	66.4	44.0	114.4	11.5	.65	42
8250	40.2	63.1	44.1	113.8	11.8	.68	42
8500	33.2	53.7	43.6	111.3	11.7	.79	43

1991 STOCK POLARIS 400XC 260MJ STOCK 400 PIPE

Data for 29.92 inches Hg, 60 F dry air
Test: 250 RPM/Sec Step Test
Fuel Specific Gravity: .745
Vapor Pressure: .19
Barometer: 30.25

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
6250	38.1	45.3	34.4	94.6	12.6	.74	41
6500	39.7	49.1	35.7	97.4	12.5	.71	42
6750	40.7	52.3	38.6	100.4	11.9	.72	41
7000	43.4	57.8	41.2	104.5	11.6	.69	42
7250	45.0	62.1	42.9	108.2	11.6	.67	41
7500	45.1	64.4	43.9	109.8	11.5	.66	42
7750	44.3	65.4	44.2	111.1	11.5	.66	42
8000	42.1	64.1	43.6	110.7	11.7	.66	42
8250	37.9	59.5	42.6	109.5	11.8	.70	42

SKI-DOO MX-X

Odyssey Recreation of Courtland, Ontario, Canada (519-688-3278) donated their new MX-X for our "certification" test. They fielded two MX-X's for the race, and their drivers, Andy and Dale Vranckx, both finished the 500 mile event.

To establish the correct safe jetting for this engine, we installed the SuperFlow air flowmeter on the main airbox opening. In order for us to measure the airflow, the two additional screen-covered holes in the rear of the airbox had to be taped shut.

We proceeded to test the engine, finding that the horsepower was a bit high. With an Air/Fuel ratio of just 10.5-1 and a BSFC of .75, the engine made around 70 CBHP. Too much power.

Trying to *reduce* this engine's output was a new experience for us; we normally have fun figuring devious means of extracting a bit *more* power from these things. What could we do?

CERTIFICATION

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Perhaps we could suggest smaller carbs or intake restrictors, lowered compression, or maybe less RV timing. As you might imagine, we hoped for a simpler solution.

We were fortunate. When we removed the duct tape from the additional rear airbox holes we feared the worst, that the engine might make even more power, but we were relieved to see the engine *lose* several horsepower! I don't know why this happened, but it's just what we needed.

With the flowmeter removed, and the airbox in its stock configuration, 390-400 main jets were acceptable for our 50+ degree F Carb Air Temperature.

1991 STOCK SKI-DOO MX-X 390-400MJ

Data for 29.92 inches Hg, 60 F dry air
Test: 250 RPM/Sec Step Test
Fuel Specific Gravity: .745
Vapor Pressure: .21
Barometer: 30.18

RPM	CBT	CBHP	FUEL	BSFC	CAT
5500	45.5	47.6	40.6	.84	53
5750	48.2	52.8	46.1	.86	52
6000	50.1	57.2	46.0	.80	52
6250	50.7	60.3	45.8	.75	53
6500	50.7	62.7	50.0	.79	53
6750	51.1	65.7	51.9	.78	53
7000	51.1	68.1	50.0	.73	52
7250	48.9	67.5	53.7	.79	53
7500	39.5	56.4	55.0	.96	53
7750	29.2	43.1	54.2	1.25	52

PROWLER SPECIAL

For the Prowler Special I-500 certification test we were supplied with a brand new engine directly from Arctco. Two different exhaust pipes were supplied with the engine. One pipe had a straight rear converging cone, (this turned out to be an EXT Special single pipe) and the other had a rear converging cone with a bend in it. (This would be the standard Prowler Special pipe). The pipe with the straight cone was designed to limit the horsepower to approximately 65 hp, while the other pipe allowed slightly more horsepower.

We installed the Prowler engine on the dyno and selected the straight cone pipe to be tested first. We performed the test with Mobil 92 unleaded and the oil injection system functional. After making six passes on the dyno, we realized the fuel supply we were using was premix! We switched to straight Mobil 92 and purged the premix from the lines.

We then installed the pipe with the turned rear cone and made some preliminary passes on the dyno. An "official" test was then performed, recording 68.1 CBHP @ 8000 RPM.

1991 STOCK ARCTIC CAT PROWLER SPECIAL CURVED REAR CONE PIPE 38MM CARBS 340MJ

Data for 29.92 inches Hg, 60 F dry air
Test: 250 RPM/Sec Step Test
Fuel Specific Gravity: .745
Vapor Pressure: .10 Barometer: 30.54

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
6250	34.2	40.7	42.1	107.0	11.7	.99	43
6500	36.5	45.2	44.4	110.6	11.4	.95	43
6750	38.2	49.1	45.8	109.9	11.0	.89	42
7000	39.5	52.6	46.4	111.2	11.0	.85	43
7250	42.4	58.5	46.2	115.4	11.5	.76	42
7500	44.5	63.5	50.7	120.6	10.9	.77	44
7750	45.5	67.1	50.8	125.1	11.3	.73	43
8000	44.7	68.1	52.6	126.4	11.0	.74	44
8250	42.0	66.0	51.6	125.3	11.2	.75	44
8500	21.9	35.4	50.6	114.9	10.4	1.37	45

Next we reinstalled the pipe with the straight rear cone and made another "official" test, this time recording 64.5 CBHP @ 7750 RPM.

1991 STOCK ARCTIC CAT PROWLER SPECIAL STRAIGHT REAR CONE PIPE 38MM CARBS 340MJ

Data for 29.92 inches Hg, 60 F dry air
Test: 250 RPM/Sec Step Test
Fuel Specific Gravity: .745
Vapor Pressure: .10 Barometer: 30.50

RPM	CBT	CBHP	FUEL	AIR	A/F	BSFC	CAT
6250	37.1	44.1	47.9	120.0	11.5	1.05	43
6500	38.9	48.1	50.6	126.4	11.5	1.01	43
6750	40.6	52.2	50.9	125.7	11.3	.94	43
7000	42.1	56.1	51.0	126.4	11.4	.88	42
7250	43.5	60.0	50.8	129.2	11.7	.81	43
7500	44.5	63.5	51.7	131.7	11.7	.78	43
7750	43.7	64.5	51.5	132.6	11.8	.77	43
8000	42.2	64.3	53.8	132.5	11.3	.81	44
8250	39.9	62.7	52.5	130.9	11.4	.81	44
8500	32.9	53.2	54.9	129.5	10.8	.99	45

When the testing was completed we measured the squish clearance above the piston pin @ .074" and the cranking pressure at 120 psi. The test results were faxed directly to the I-500 race committee. Since the other engines tested for the race made approximately 68 CBHP, it was ruled that the pipe with the turned rear cone (68.1 CBHP) would be allowed in the Prowler Special.

Special thanks to DynoTech contributing editor Tim Taylor, who assisted with the Prowler Special certification, and provided the report on the test session.

AN INSIDE LOOK at the V-MAX 4

The V-Max 4 prototypes that we have seen on display around the U.S. and Canada are missing CDI boxes or other vital components. Because of this, we have been as yet unsuccessful in our quest to obtain one for public dyno analysis.

However, I recently acquired a used (but clean) Olympus proctoscope from a bankrupt health care facility in Albany, N.Y.. With its flexible 30 inch long fiber optic probe, the proctoscope enabled me to travel up through the Y-pipe and examine the inner sanctum of a prototype V-Max 4's cylinder. The proctoscope was equally useful in snaking its way through the airbox and carb bodies to examine the reed cages and intake port.

Here are some of the technical, performance related highlights of the V-Max 4, most of which were correctly predicted by the Cellar Dweller (see "Pure Speculation" in V2#3 and "More Fantasy Based On Rumor" in V3#1).

* All MIG welded aluminum chassis and bulkhead, aluminum skis, supposedly making the V-Max 4 "lighter than a Polaris RXL".

* Hood is loaded with functional air ducts. The crankcase, radiator, brake, (cable operated, huge jackshaft mounted disc), and twin air boxes should receive cold outside air.

* Inline four cylinder engine, 743 cc displacement, 63mm bore x 59.6mm stroke, cylinder reed induction, fixed height single exhaust ports. One head for each "pair" of individual cylinders.

* Engine rotates "backwards". A gear in the center on the crankshaft drives a counter rotating, reduced speed (supposedly 5% underdriven) drive clutch jackshaft in the opposite (normal) direction. This shaft is mounted on the ***front*** of the crankcase. Thus, the engine weight is moved toward the rear of the bulkhead, and the drive clutch spins ahead of the crankshaft centerline. The gear in the center of the crankshaft also drives the water and oil pumps, which are mounted on the rear of the crankcase.

* Engine cooling water is pumped through the rear of the crankcase, up through the cylinders, then through the heads. Exciter tunnel heat exchangers are used, as well as a short, wide radiator mounted ahead of the engine.

* The variable ratio oil pump injects oil directly into two newly designed (something other than the standard Mikuni) fuel pumps.

* Six fiber petal, Phazer-sized reed cages, with two Phazer-like "boost tubes" connecting each pair of intake flanges.

* 90 degree firing order, with non-adjustable, digital ignition mounted on the PTO end of the crankshaft. The other end of the crank is used only for the manual rope start.

* Twin insulated pipes, appearing very much like those on the '81 SRX, empty into a large cannister muffler. Twin Y pipes, with tantalizingly long, straight connecting pipes are used. Power peak should be @8250 RPM. There is plenty of room under the cavernous hood for two more pipes.

* Four 33mm Mikuni flatslide carbs are used. These are rack mounted, motorcycle style. The use of a single throttle cable and the shaft/ linkage slide control results in a very light throttle pull. Two open-looking, separate airboxes feed outside air to the engine. Airbox removal to facilitate carb servicing appears easy.

* Layered, Exciter-style, coated steel headgaskets are used. These are dreaded because they are expensive and shouldn't be reused. However, they are nice for altering compression and squish clearance by simply removing one or more of the gasket layers before installing them.

PIPE SHOOTOUT# 17

1991 MACH IX

Tom Smith of Smith Marine in Old Forge, N.Y. donated George Taylor's Mach 1X for our first 617 Rotax pipe testing session.

This is the same Mach 1X we used in the Battle of Old Forge. Since then, Tom had increased the compression by cutting .020" from the head surface, leaving a net squish clearance of approximately .050".

By most standards, this is a tight head for pump gas. George had just returned from a 450 mile "spirited" ride on Quebec trails and pump gas, and the engine had no problem surviving the trip with the standard main jets. However, he was admittedly judicious with the extended application of full throttle on Quebec's notoriously low octane gasoline.

For our first test we've retained the high torque stock single pipe. Referring to the data in the last issue on the 1991 stock Mach 1, we can see how the installation of the higher compression head, larger carbs and Mach IX rotary valve might influence the power curve.

1991 STOCK MACH I 450-500MJ
STOCK SINGLE PIPE 84dB
Data for 29.92 inches Hg, 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .710
Vapor Pressure: .20
Barometer: 30.22

RPM	CBT	CBHP	FUEL	BSFC	CAT
6000	68.1	77.8	60.1	.76	42
6250	69.4	82.6	65.4	.77	42
6500	70.2	86.9	67.1	.75	43
6750	72.3	92.9	68.9	.72	41
7000	76.2	101.6	72.9	.70	41
7250	77.3	106.7	75.3	.69	41
7500	76.0	108.5	79.1	.71	42
7750	46.5	68.6	76.8	1.09	41
8000	41.6	63.4	75.6	1.16	41

Comparing the 1991 stock Mach 1X data in the last issue, we can appreciate the benefit of the higher compression head on the same twin piped engine. Torque and horsepower have been increased, particularly in the midrange.

1991 STOCK MACH I 450-500MJ
STOCK TWIN PIPES 86dB
Data for 29.92 inches Hg, 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .710
Vapor Pressure: .20 Barometer: 30.24

RPM	CBT	CBHP	FUEL	BSFC	CAT
6250	59.2	70.4	59.7	.83	43
6500	63.2	78.2	64.0	.80	43
6750	65.3	83.9	66.0	.77	42
7000	68.8	91.7	69.7	.74	43
7250	71.2	98.3	70.3	.70	43
7500	72.2	103.1	74.0	.70	44
7750	72.1	106.4	75.6	.69	43
8000	72.2	110.0	78.2	.69	41
8250	73.2	115.0	79.3	.67	43
8500	71.6	115.9	77.4	.65	44
8750	68.0	113.3	77.8	.67	44
9000	61.2	104.9	80.6	.75	43

Decker Racing Enterprise's twin pipes were the only ones tested which had their own individual glass packed silencers. While they were louder than the other stock cannister pipes, they also saved a bit of weight.

These had the highest peak horsepower, but lowest torque of any of the pipes.

1991 STOCK MACH I 450-500MJ
DECKER PIPES 94dB
Data for 29.92 inches Hg, 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .710
Vapor Pressure: .20 Barometer: 30.23

RPM	CBT	CBHP	FUEL	BSFC	CAT
6250	60.2	71.6	60.5	.83	46
6500	64.5	79.8	65.2	.80	45
6750	65.9	84.7	69.2	.80	45
7000	67.1	89.4	73.2	.80	45
7250	67.8	93.6	75.3	.79	44
7500	69.5	99.2	76.9	.76	46
7750	70.0	103.3	76.4	.72	46
8000	70.1	106.8	77.4	.71	36
8250	70.0	110.0	79.4	.71	44
8500	71.9	116.4	80.0	.67	45
8750	71.3	118.8	79.8	.66	46
9000	53.4	91.5	81.2	.87	45

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This year, the Crankshop began producing their own stamped twin pipes for the Mach 1 617 engine. Utilizing the quiet stock cannister, the standard length Crankshop pipes made a great deal more torque and midrange power than the standard X pipes, but a bit less peak power.

1991 STOCK MACH I 450-500MJ CRANK SHOP PIPES dB

Data for 29.92 Inches Hg, 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .710
Vapor Pressure: .20 Barometer: 30.23

RPM	CBT	CBHP	FUEL	BSFC	CAT
6000	60.4	69.0	54.9	.78	48
6250	59.6	70.9	57.3	.80	50
6500	61.8	76.5	62.7	.81	49
6750	68.4	87.9	67.2	.75	46
7000	72.2	96.2	69.8	.71	47
7250	73.5	101.5	71.8	.69	47
7500	74.3	106.1	74.6	.69	48
7750	74.0	109.2	75.2	.68	47
8000	73.5	112.0	80.5	.71	47
8250	73.2	115.0	80.6	.69	48
8500	70.0	113.3	81.1	.70	47
8750	63.8	106.3	79.4	.73	48

What if you had a '90 stock 580cc Mach 1, and someone convinced you that "stroking" the engine to 617cc would be the hot ticket for big H.P. with your stock '90 single pipe? Here's the test data that resulted from installing a '90 single pipe on the '91 617 engine.

1991 STOCK MACH I 450-500MJ 89 SINGLE PIPE dB

Data for 29.92 Inches Hg, 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .710
Vapor Pressure: .20 Barometer: 30.22

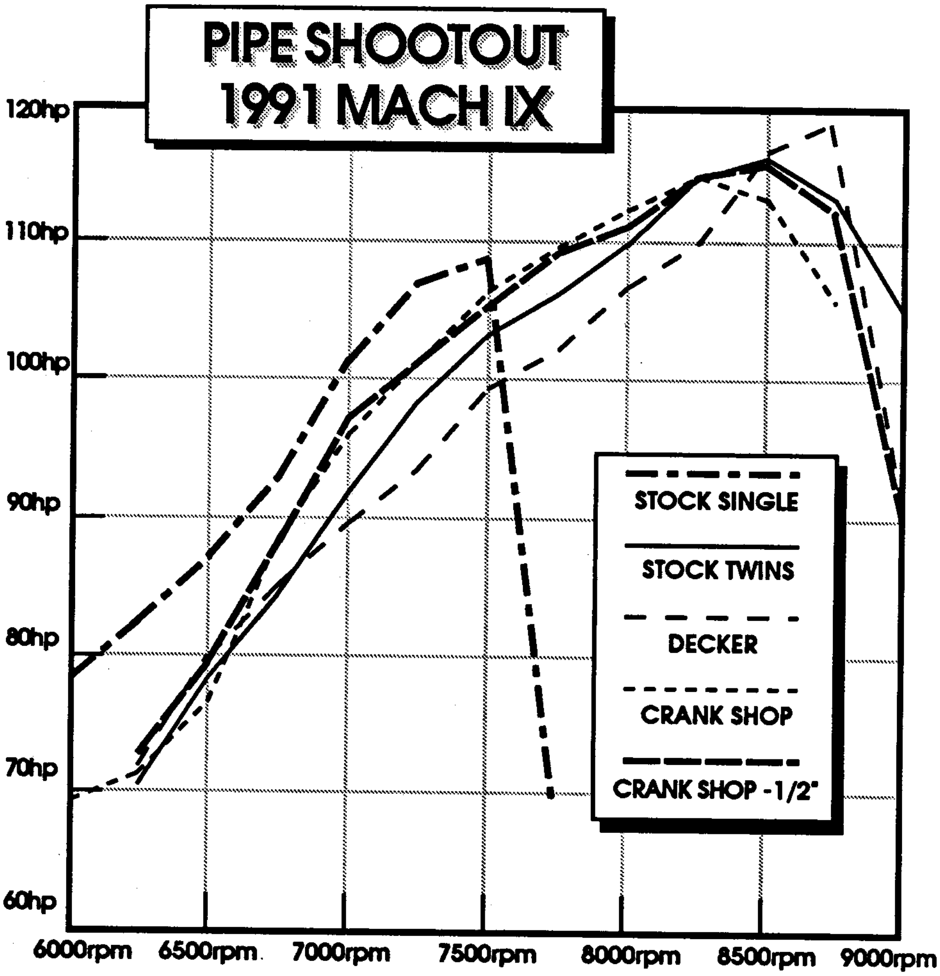
RPM	CBT	CBHP	FUEL	BSFC	CAT
5500	65.3	68.4	59.0	.85	44
5750	66.6	72.9	56.8	.76	44
6000	67.8	77.5	62.9	.79	44
6250	68.0	80.9	68.3	.82	43
6500	65.6	81.2	70.2	.85	43
6750	60.3	77.5	72.5	.91	44
7000	47.4	63.2	73.8	1.14	42
7250	43.9	60.6	74.7	1.20	43
7500	42.1	60.1	76.3	1.24	43
7750	39.6	58.4	72.7	1.21	44

Removing 1/2" from the header pipes of the Crankshop pipes brought the power peak up 250 RPM. Now the pipes matched the peak horsepower of the X pipes, but still had a considerable midrange torque and horsepower advantage over the other twin pipes. With 1/2" removed from the pipes, there was no problem fitting the pipes to the flanges and into the stock cannister.

1991 STOCK MACH I 450-500MJ CRANK SHOP PIPES -1/2"HP dB

Data for 29.92 Inches Hg, 60 F dry air
Test: 100 RPM/Sec Acceleration
Fuel Specific Gravity: .710
Vapor Pressure: .20 Barometer: 30.21

RPM	CBT	CBHP	FUEL	BSFC	CAT
6250	61.1	72.7	61.4	.83	42
6500	63.7	78.8	63.6	.79	44
6750	68.8	88.4	68.8	.76	42
7000	72.9	97.2	72.4	.73	43
7250	73.5	101.5	73.6	.71	43
7500	73.8	105.4	76.1	.71	42
7750	73.8	108.9	77.6	.70	43
8000	72.7	110.7	78.6	.69	38
8250	73.2	115.0	78.5	.67	43
8500	71.3	115.4	79.6	.67	44
8750	67.2	112.0	79.1	.69	43
9000	52.5	90.0	79.6	.86	43



FEEDBACK JIM CZEKALA

'91 EXCITER UPDATE

Craig Sessions (V3 #1;'91 Exciter Pipe Shootout) has been closely monitoring the airbox temperature on his stock '91 Exciter. Using a twin probe electronic temperature gauge that we loaned him, Craig has found that his Exciter's Carb Air Temperature normally runs 30 degrees F hotter than the outside air temperature. Using our dyno test results and his Mikuni slide rule, Craig has been using 230 main jets at sea level, 20 degree F outside air temp (50 degree F CAT) . This has been a 92 octane safe spec for him.

Craig has since purchased and installed a cold air induction kit from Bender Racing. Now, at 20 degrees F outside air temp his Carb Air Temp is 20 degrees F. This necessitated an increase in main jet size to 240, and resulted in about a three percent increase in horsepower due to the denser, colder intake air.

'88 WILDCAT AIR INTAKE

I recently met Pennsylvania subscriber Rich Curtis while trail riding in the Old Forge, N.Y. area. He related to me some problems that he had experienced trying to tune his trail mod '88 650 Wildcat.

He had been using strangely tiny main jets to obtain decent piston readings and/ or exhaust gas temperatures, which he felt may have been caused by an air restriction.

Apparently, the stock '88 air intake louvers in the seat are inadequate for a mod 650 like Rich's, with early FIII porting, 44mm carbs, and a gutted airbox. He purchased and installed the later style, tank cover mounted air louvers. The change allowed him to use larger main jets and greatly increased the sled's performance.

BATTLE OF OLD FORGE CORRECTION

In the last issue, I goofed when I wrote that American Snowmobiler had made an error on the RXL's quarter mile E.T..

Recently, while reviewing part of a videotape of the shootout, I could vividly hear the 13.65 second E.T. announced after Tim Bender made his second quarter mile run on the RXL, just as American Snowmobiler had reported.

V-MAX 4

Tim Bender told me that Bender Racing will be getting a few V-Max 4's from Yamaha. Tim says they are going to be "stepping up the engines and chassis'", and selling them as special performance consumer sleds.

SNO-MAX OIL

E.J. Schweitzer of Maxline sent us a couple of quarts of Snomax premix and injection oil to dyno test.

Using Dan Cross' C-14 fueled 750cc mod Polaris engine with HTG quiet pipes as a test engine, the 750cc engine made two more horsepower with Polaris oil than it did with Snomax.

Then, switching from mufflers to loud stingers, the results were totally reversed! The Snomax oil made two more horsepower than the Polaris oil. Dan's engine made the same horsepower with quiet pipes and Polaris oil as it did with loud pipes and Snomax oil.

We ran some of the leftover C-14 and SnoMax oil in another full mod Polaris engine, and the engine's owner found that the crankshaft and rods had an unusually heavy coating of oil after our dyno session.

What does all this mean?

As with different brands and types of gasoline, oil brands and types are difficult to catagorize as being "better" than one another; every engine/pipe/ timing combination will be "happiest" with a particular gasoline and oil. The variations in engine performance, however, are very slight, and require an instrumented dyno to detect and analyze.It is easy to spend a day on the dyno testing different gasoline/ oil combinations and perhaps find one or two horsepower.

I generally try to discourage typical dyno users from spending time and money on gasoline and oil comparisons. The exception would be serious lake or track racers, for whom one or two horsepower might mean the difference between winning and losing. ➡

FEEDBACK

T.C.D.-VOLATILE SPIRITS

Kevin Cameron's last essay, "Volatile Spirits", and "Tuning and Temperature" in V2 #6, turned on the light bulbs in many of our minds. It also enlightened me as to why some seemingly unsolvable mysteries have occured on our dyno in the past.

Our interest in fuel volitility and its relationship to performance was sparked several months ago when we were dyno tuning a Yamaha TZ250 roadracing motorcycle for one of Kevin's associates. They had been using 105 octane (R+M/2) VP C12 gasoline in the engine, which had an uncorrected compression ratio of nearly 20-1 (!!!), and had been detonating the engine on long straightaways with jetting that would calculate to a BSFC of more than .70! Sure enough, we began to deto the engine on the dyno with long, slow pulls at the same .70+ BSFC.

After having tuned several hundred high compression snowmobile engines, I was certain that we could safely tweak some more horsepower out of this engine if we used better gasoline. Drawing a few gallons of 114 (R+M/2) octane, C14 from the barrel in the corner, we proceeded to lean the engine down to a BSFC of .60, where the midrange and peak power was considerably higher and there was no sign of detonation. I was quite proud of having suggested the fuel change.

Then we noticed that beyond the higher power peak, the horsepower was greatly reduced by our C14 gasoline. With the C12, the TZ250's torque and horsepower tailed off gradually beyond the peak. With the C14, the power curve dropped like a proverbial rock after the peak.

While this would be of less consequence on a properly clutched snowmobile, it would certainly cause problems on a roadracing motorcycle that required a broad powerband both before and after its 11,000 RPM power peak. The net result was that the TZ250 was better off with the C12, even though we couldn't jet for the greater lean horsepower that was survivable with the C14.

When I telephoned Kevin to discuss our unusual dyno results, I could hear his chin whiskers being grated between his thumb and forefinger. The wheels were turning.

Kevin spent the next few days boning up on current high octane gasoline technology, which apparently has changed little since World War II. Later, he enlightened me on the variations in gasoline volatility. This would explain the phenomenon we experienced on the high RPM Yamaha; the less volatile C14 didn't have the **time** necessary, at 11,000+ RPM to vaporize properly. In essence, we had leaned out the engine at high RPM to the point that horsepower dropped dramatically. The gasoline was there, present in the air going through the engine, but much of it was sailing through the engine in comparatively large, unburnable lava lamp-like globules.

This condition may have been aggravated by the fact that our C14 was several months old, and the "front ends" of the gasoline probably had been lost to the atmosphere. What's left behind, after several months of less than perfect storage is more difficult to vaporize. It now requires a great deal more heat and turbulence-induced agitation to vaporize and burn.

Oh, yeah! Now I remembered the early days as a rookie dyno operator. Knowing little about fuel flow and air/ fuel ratios, we relied heavily upon exhaust gas temperatures to tune racing engines. I learned early-on that different engines could withstand different EGT's. But when we once seized a 440 SRX high compression mod engine at 950 degrees F, I was convinced that our SuperFlow exhaust probes were faulty. I am more convinced now that the SRX owner's racing gas was old; the excessive unburned fuel was only cooling our exhaust probes, leaving us with a false sense of overrich fuel flow that could surely be rectified with smaller main jets. Wrong.

Last fall we detonated a safely jetted (.70 LB/HPHR) 11,000 RPM SkiDoo Sno-Pro 250 by removing the thermostat to lower the engine coolant temperature. It baffled us then, but now I understand why. The gasoline we were using needed the high engine temperature to vaporize correctly at those wickedly high RPM's.

More recently, there was our own turbocharged Indy 500, sputtering on the dyno with an A/F ratio of 10-1. What I thought was a "rich" sputter turned into detonation, which seized one piston,and left the other one dangerously dry. Some three month old C16 racing gas, stored in a plastic jug in the trailer, was the culprit. Having absolute confidence in the dyno's air and fuel flow meters,

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FEEDBACK

I replaced the burned piston, opened a fresh drum of C16, and had no more problems. The engine was even happier with lowered fuel flow, and made much more horsepower at around 13-1.

I've heard from many subscribers who have had similar experiences with racing engines that "mysteriously" overrichen when engine or air temperatures rise. Others have suffered weird siezures with huge main jets. These problems can usually be traced to less than fresh gasoline.

We're all relieved to have logical answers to these and other Great Mysteries.

FUEL STORAGE

We've all gradually used large liter bottles of Pepsi Cola, only to find them lose some of their fizz each time the cap is removed. After a week or so, at the bottom of the bottle, there's not much carbonation left.

Perhaps we can compare the loss of carbonation in unpressurized beverages with the loss of the important, highly volatile "front ends" in some unpressurized racing gasolines.

With this in mind, I've asked my machinist pal Skip Saupe to turn out some aluminum, threaded and o-ringed barrel "DynoTech Bungs", similar to those used for draft beer. With these, we now blanket and pressurize all of our stored gasoline with inert Nitrogen gas (N2).

The Nitrogen pressure pushes the gasoline from the barrels as it's needed, by the same method in which CO2 pushes beer from a keg, while holding the beer's carbonation in suspension indefinitely. Nitrogen is an ideal blanketing gas. It contains no moisture, will not support combustion, will not oxidize the gas, and is inexpensive.

We use a two-stage regulator to maintain the 2-3 P.S.I. (gasoline barrels have a design limit of 15 P.S.I.) of Nitrogen head pressure that's necessary to blanket the gasoline and push it from the barrel on demand. A small manifold will feed Nitrogen to the four different barrels we keep in use at all times.

A separate siphon hose in each bung draws gasoline from the the barrel. No pumps are needed; the pressurized Nitrogen does the job.

Nitrogen gas is available from any welding supply house in cylinders varying in size from 20 to 300 cu.ft. Nitrogen valves are universal. It takes less than 10 cu.ft. to protect and transfer 50 gallons of gasoline.

If 50 cents worth of Nitrogen will ensure the quality of $250 worth of gasoline (and the well being of our expensive engines), the DynoTech Bungs should be a "must" for anyone who uses drummed gasoline. No reason to use up your leftover racing gas in your pickup truck; the Nitrogen blanket will keep the fuel safe and factory fresh for years.

We will include price and ordering information in the next issue. Anyone interested in more information can inquire through DynoTech, Box 801 Dept. B, Batavia, N.Y. 14021.

The bungs will be available directly from DynoTech or Bender Racing. Canadian residents wishing to purchase DynoTech Bungs can obtain them from Arnprior Sportland (613-623-4410).

IMPeRFeCT MIXTURES

THE CELLAR DWELLER KEVIN CAMERON

We are all accustomed to thinking of detonation as being mainly a matter of adequate fuel octane and not too much of either compression ratio or spark lead. Quite right; those variables will usually bring deto under control when correctly used. We also know that combustion chamber shape is important. At the same compression ratio, a turbulent head (with squish, for example) may not knock, while a so-called "quiescent" head (no artificial turbulence-generating shape) may knock badly. The temperature of the interior combustion chamber walls is important as well, as is mixture temperature; the cooler the chamber and/or the mixture, the cooler the combustion, and so the less likely knock becomes. But there are other important variables - often overlooked.

During World War II, Allied combat aircraft burned 100 octane fuel. Indeed, the availability of this fuel is sometimes credited with giving Britain the margin of victory in its defense against German bomber attack in 1940.

What is not so widely known is that Germany's standard aircraft fuel was rated at approximately 80 octane, yet German aircraft engines were not inferior in power or reliability to Allied types. How could this be? A difference of twenty octane numbers at the same power level ought to have sent German engines into paroxysms of terminal detonation, yet they did not. Why?

The difference was in the mixture formation. Allied engines, at least through most of the war, were carbureted by a single carburetor delivering fuel into the supercharger eye. All German aircraft engines were fuel injected at very high pressure (1200 PSI).

A thoroughly homogenous fuel-air mixture burns faster than does a partially evaporated patchwork of rich and lean zones, plus various size fuel droplets still in the process of evaporation. The British engines, burning such a patchwork mixture, needed very high octane to protect them from detonation. Most of the value of that high octane was in protecting the lean cylinders from their natural tendency to detonate.

In the German engines, high injection pressure produced a fine droplet size and also produced high injection velocity. Evaporation takes place fastest when there is rapid relative motion between droplets and air; either the droplets move slowly and the air moves fast, (carburetors) or the air moves fast and the droplets move faster still (high pressure fuel injection).

Also, the German engines achieved equal fuel distribution to all cylinders automatically; fuel was sent to each cylinder in identical size shots.

When using a single carburetor on any kind of multi-cylinder engine, it is rare that any two cylinders receive the same mixture. Some are rich, some are nearly right, some are lean. When a cylinder runs lean, there is the risk of residual flame after combustion, and with it, backfire. Imagine what that does to a large aircraft intake manifold, packed with mixture. In the pre-war era, the Italians developed an extremely powerful racing aircraft engine, but its fatal weakness was catastrophic backfires from unequal fuel mixture distribution. The "answer" was to improve distribution as best one could, then "cover" the remaining problem with overrichness.

During the 1930's, the U.S. auto industry did a lot of high compression research, anticipating a future in which higher octane fuels would be available. They discovered just what you would expect - that power and efficiency increased with higher compression ratios, provided that detonation could be prevented. Some of this research was done with triptane, a pure hydrocarbon with enormous anti-knock properties (it is now be-

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THE CELLAR DWELLER

ing used in air racing, but it's not cheap). As in the case of the aircraft engines, triptane's high octane "covered up" the problems of unequal fuel distribution.

A more basic approach was to build an engine with a fuel system that delivered identical, homogenous mixtures to each cylinder, and then compare that with carburetors. This was done with fuel injection equipment. In the case of one six-cylinder engine, served by a single carburetor, the fuel injection version gave 22% more power while using less fuel and requiring less octane numbers than a carb version. This is impressive stuff, because it shows the extent to which large fuel droplets do not vaporize, and the extent to which unequal distribution occurs.

Here at the C&H Dyno, an IRS fuel-injected engine was baselined for torque curve, using 44mm throttle bodies. Feeling that the engine needed more air, Jim retested it with special 46 mm Mikuni round-slide carburetors. After varying the mixture back and forth to locate best power, he was surprised to find that the injected engine gave 5 BHP more than the big carburetor version, despite the fact that the carbureted engine was flowing more air. The difference has to be attributed to mixture quality differences. The FI engine burned more mixture than did the carbureted engine - even though the carb engine flowed more mixture. Getting a lot of mixture in is only half the battle.

Jim would probably find that the FI version could run higher compression, with less spark lead. My point here is that fuel injection is not just an electronic carburetor. It is a different way of forming a mixture, and may permit or require other changes in tune that could be beneficial. A more thoroughly evaporated mixture will burn faster (less spark lead) and therefore will tend to detonate less (detonation conditions take time to develop; the faster the burn, the less deto), and make more power (the mixture isn't carrying non-burning big droplets that rob heat from combustion).

Fuel injection systems vary in their ability to break up fuel into droplets. Automotive systems, operating at 60-90 PSI, may be inferior to carburetors at lower throttle positions.

Thinking of the value of a uniform mixture, I began to think of all the things that could contribute to it. The first is intake velocity. If intake size is moderate to small, velocity is high and the fuel droplets will have a violent ride that evaporates them well. If intake size is large, intake velocity falls and there may be some loss associated with poorer vaporization. In fact we see such an effect in real life. In the past, I have thought of the value of intake velocity in terms of the ram effect - a fast moving charge can keep piling into the crankcase long after the piston has started down again. Maybe I should also think of the value of intake velocity as a means of improving fuel/air mixing.

And what about in-cylinder turbulence? In the first place, it is caused by the motion of the cylinder filling process, which is rapid at first. Then, as the charge is compressed, its viscosity increases and the original motion is slowed - by perhaps as much as a factor of ten. This is the in-cylinder motion that is present at the moment of ignition. If, by this moment, the charge is sufficiently mixed to have a high burning speed, ignition will take place speedily, and burning will follow as quickly. Traditionally, we think of turbulence as something that mechanically accelerates flame spread. What if, in fact, turbulence works in another way as well - by stirring the cylinder contents, thereby taking a last-moment crack at evaporating fuel and producing a homogenous mixture?

DYNOTECH is an independent newsletter published by **DYNOTECH** Corp., P.O. Box 801 Batavia N.Y. 14021 in affiliation with C&H Dyno Service, 8 Apollo Drive, Batavia, N.Y. 14020. Subscription rate is $30.00 per year (six issues). Phone 716 344-1313. No part of this publication may be printed or otherwise reproduced without express permission from the publisher. Send address changes to **DYNOTECH**, P.O. Box 801, Batavia, N.Y. 14021. **DYNOTECH** makes every effort to assure the accuracy of articles and technical information listed in this newsletter. **DYNOTECH** assumes no responsibility for damages due to errors, omissions, or application of any information.

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