BENDER RACING'S TURBOCHARGED 2003 YAMAHA RX1…
By Jim Czekala

There's nothing to compare to pumping air/ oxidizers into an engine to make more HP.

Four-cycle engines are more fuel *and* air efficient than two-cycle engines. Generally speaking, four-cycle engines can be operated at high output with only .4-.5 lb/hphr BSFC whereas two-cycles typically require .6-.7 lb/hphr to operate reliably. The two-cycles' higher fuel consumption is a combination of necessarily richer A/F ratio combined with higher air consumption (Brake Specific Air Consumption).

The Aerodyne model 53000 turbocharger has the airflow capacity to create a maximum of about 190-210 HP on two-cycle sled engines. Looking back in our past issues where turbocharged two-cycle engines are shown, we typically would see airflow of about 330 CFM required to make 200 HP on mildly ported engines like the '92 750cc Vmax4. More radically ported engines (like '93 and later Vmax 4 750's) are not as happy with a turbo, and BSAC is even higher on those engines. As I recall, the '93 and later Vmax4 750's made closer to 190 HP with 330 CFM of turbo airflow. Based upon the following test data created on our dyno with Bender Racing's first turbocharged production RX1, that same 330 CFM should make about 250 HP on the highly tuned, very efficient 1000 cc four-cylinder engine.

Bender Racing is planning to sell turbo kits in three configurations:

1) A base model with a slick extruded tunnel heat exchanger (snow-air) intercooler with 4 psi boost and 180 HP on pump gas.
2) The same base model with twin intercoolers; the tunnel heat exchanger plus an airbox mounted air-air intercooler with 8 psi boost and 220 HP on 100 octane (av gas or 50/50 race gas/ 93 octane mix).
3) Twin turbo (or a single larger unit), gonzo-boost with 300 HP, race gas only.

Some comments about these seemingly bizarre power numbers. I am biased because I am part owner of Aerodyne Corp. (formerly called First Choice Turbo) who manufactures the unique self lubricating, ceramic ball bearing, variable vane exhaust, Aerocharger® turbocharger. We have sold some 2000 turbo kits for sleds. In early DynoTech issues, to the chagrin of my Aerodyne partners, I commented that two-cycle turbo sleds were only desirable for those who were the most savvy clutch/ carb tuners. My early experience trail riding/ mountain riding turbo sleds is that the very best turbo-tuners will enjoy crisp throttle response (at best, a bit spongy on the trail because of the monster-weights necessary for on-boost operation) with dragster holeshots and superb on-off-on throttle performance even on multi-minute-long vertical mountain blasts. But, if you've got the wrong pilot jet, float setting or clutch spring, you can have 100 foot long bogs, or find your crankcase loaded with fuel after getting off the gas on a mogul trying to get to the top of a mountain. And even worse-- if you mismatch boost/ A/F ratio/ octane level all boosted two-cycles will quickly, inaudibly, and expensively detonate and fail without warning and put you on the trailer (which is hopefully nearby). A deto'd and crumbled piston will take out a nickasil cylinder before it takes out the vanes and exhaust turbine in the turbo. Maybe $2000 for a few seconds of indiscretion? With boosted two-cycles, OCTANE IS YOUR FRIEND.

Since our early sled kit days where we manufactured and sold 2000 two-cycle kits, Aerodyne has sold 2000 turbo kits for Harleys and Ford Focuses, and another 2000 Aerochargers that have been installed by other turbo tuners on other motorcycles and cars. I have 60K miles on a twin-Aerocharged 5.3 liter Silverado (400HP and 550LB/FT) that has happily towed huge trailers full of turbo Harleys to Daytona Bike Week. I had in our garage for a year an Aerocharged 1100cc Honda Blackbird motorcycle that was perfectly reliable with 240 crankshaft HP on pump gas for those short periods of time that you could hold the throttle open. All of our 2000 Harley customers' Aerocharged engines make double (or even triple or quadruple) the stock HP, and all can be driven coast to coast. A/F ratio too lean? The pipes turn red and your trousers ignite. Jet up and your trousers are fine. Too much boost for the octane you just bought? Deto is usually audible on four-strokes and when being annoyed by the clicking, clacking and snapping of loud detonation anyone with an IQ of more than 60 will reduce the throttle opening and/ or lower the boost! The good news for four-cycle deto-ers is that every violent detonation stroke is followed by a relaxing, piston-cooling intake stroke. That helps give you time to react. Boosted four-cycle engines are like going to heaven. Will the RX1 reward you with audible warning if you try to run 10 psi boost on 79 octane "bar gas" left over from last season? I believe so, but we'll have to wait to see how this unfolds. My pleading with Bender's Terry Paine to try some 87 octane at 200 HP to see what detonation we might experience/ hear on the dyno was rewarded with a raised middle finger pointed in my direction.

How is it that a 141 HP RX1 engine will not explode when boosted to 280 HP with proper octane? Doubling an engine's power with boost only increases peak combustion chamber pressure (at about 20 degrees ATC) and resulting compression loads on parts by only 20%! Of course, tension loads on components remain stock because HP peak remains stock or thereabouts. Boosted engines get most of their performance increase by multiplying combustion chamber pressure well beyond the 20 degree ATC peak, dramatically extending the power stroke, possibly quadrupling residual combustion chamber pressure over stock at 90 degrees ATC! This not only minimizes added compression loads on parts, but can reduce torsional vibrations to boot.

Conversely, adding HP by adding revs with big cams will increase tension loads on parts as the square of engine speed. That is the law of physics. If you install dragrace cams in the RX1 and raise the power to peak to, say, 175 @ 14,000 RPM you will DOUBLE tension loads on rods and parts! Boost is best, no matter how you get it.

Turbochargers- make boost without sacrificing power. They are driven by waste exhaust energy. Boost curve (low RPM to high RPM varies dramatically with turbo design). In the case of the Aerocharger on the RX1, full boost is achieved at 5-6000 rpm and lays flat to power peak. Turbo lag, while varying with design, is the time required to spool turbocharger up to make meaningful boost pressure. Lag can vary from being unnoticeable to annoying or worse depending on turbo design.

Centrifugal superchargers- take HP to drive, efficient at high revs, maybe require 15 HP to drive to create 200 HP worth of air. Boost increases as the square or engine speed, 8 psi boost at 12000 rpm = 2 psi at 6000! This boost characteristic results in very poor midrange torque.

Roots-type or screw-type superchargers- take more HP to drive, about 20HP to make 200 HP. Roots type makes boost in direct proportion to engine speed—8 psi at 12000 = 4 psi at 6000. Screw-type is better giving you closer to 5 or 6 psi at 6000. These direct drive superchargers reward you with instant boost as throttle is opened but with lower midrange boost than quick-boosting turbos deliver. Since 15-20 HP will be lost driving a supercharger, if someone manages to create an intercooled RX1 supercharger kit, it will require about 8 psi boost to net 200 HP at the output shaft. If a good intercooler is not used, maybe 10 psi will be required to hit the magic 200 with a supercharger.

Our resident clutchmeister Sean Ray commented on the following horsepower curves. Note the flatness, even flatter than stock, meaning that the HP is virtually the same from 9800-10,900 and Sean figures that even I can clutch that. There are two distinct benefits to a flat horsepower curve like that:
1) a "pump gas" low boost setting can be clutched to run on the low side of the horsepower curve, and boost can be added with high octane gas and a toggle switch and the extra power will drive the RPMs higher yet still be in the power band. This means you can add, say, 50 HP with boost and octane and not have to touch the clutching/ gearing for optimum performance!
2) those who will be happy staying with 180 HP pump gas setting can clutch that power toward 10,900 RPM using lighter weights and/ or straight helix', which should result in very un-turbo-like, very crisp backshifts for trail riding.

Note that we instrumented the sled to show dyno room temp, compressor outlet temp, temp after the first intercooler under the tunnel, and temp after the final air-air intercooler. The two-stage intercooler is extremely efficient, dropping compressed charge air temp almost back to ambient! This creates greater air density and reduces the possibility of detonation. Also, the carb venting allows correct fuel flow even with all stock jetting in the CV carbs.

The SuperFlow dyno measures intake manifold pressure in inches of mercury (in Hg). Two inches of Hg = one psi boost.

EngSpd RPM	STPTrq Clb-ft	STPPwr CHp	BSFC lb/hph	ManPrs inHg	WtrOut degF	FuelB lb/hr	A/F Ratio
5300	88.2	89.0	0.52	7.3	157	45.4	12.2
5400	87.9	90.4	0.51	7.4	157	45.2	12.2
5500	88.2	92.4	0.50	7.4	157	45.0	12.2
5600	88.4	94.3	0.49	7.4	157	44.9	12.3
5700	89.5	97.2	0.47	7.6	157	44.8	12.4
5800	92.1	101.7	0.46	7.7	157	45.7	12.3
5900	93.1	104.6	0.44	8.0	157	45.0	12.7
6000	94.2	107.6	0.44	8.2	157	45.6	12.8
6100	94.5	109.7	0.43	8.3	157	46.1	12.8
6200	95.1	112.3	0.44	8.4	157	48.3	12.6
6300	95.4	114.4	0.44	8.4	157	48.6	12.8
6400	96.0	117.0	0.42	8.5	158	48.1	13.3
6500	95.7	118.5	0.42	8.5	159	48.2	13.5
6600	95.4	119.9	0.42	8.4	158	48.4	13.6
6700	95.9	122.4	0.42	8.4	158	50.1	13.4
6800	95.7	123.9	0.43	8.4	158	51.2	13.3
6900	96.2	126.4	0.42	8.4	158	51.1	13.6
7000	96.7	128.8	0.42	8.5	158	52.0	13.6
7100	95.9	129.7	0.42	8.5	159	53.5	13.4
7200	95.4	130.8	0.42	8.5	159	53.9	13.5
7300	95.9	133.4	0.42	8.5	159	54.5	13.5
7400	97.0	136.6	0.43	8.4	159	56.9	13.2
7500	97.2	138.8	0.42	8.6	160	56.2	13.6
7600	97.8	141.5	0.42	8.6	160	57.6	13.5
7700	98.5	144.5	0.42	8.7	160	59.1	13.4
7800	97.7	145.1	0.42	8.7	161	59.3	13.7
7900	97.3	146.4	0.42	8.7	161	59.3	13.8
8000	98.1	149.5	0.41	8.6	161	59.6	14.0
8100	99.8	153.9	0.40	8.7	161	60.1	14.2
8200	99.7	155.6	0.41	8.7	161	61.5	14.1
8300	100.3	158.5	0.41	8.7	161	63.3	14.0
8400	100.1	160.1	0.42	8.5	161	64.6	13.8
8500	99.1	160.3	0.41	8.4	161	64.3	14.1
8600	99.5	162.9	0.42	8.5	161	66.0	13.9
8700	99.4	164.6	0.41	8.7	162	66.2	14.1
8800	98.8	165.5	0.41	8.9	162	65.9	14.4
8900	98.6	167.0	0.41	8.8	162	66.6	14.4
9000	98.1	168.0	0.41	8.8	162	67.5	14.4
9100	98.6	170.8	0.45	8.8	163	73.9	13.2
9200	98.1	171.8	0.46	8.9	163	77.4	12.8
9300	97.7	172.9	0.48	8.8	164	80.6	12.4
9400	97.2	174.1	0.47	8.9	164	79.4	12.8
9500	96.7	175.0	0.48	8.8	164	81.3	12.7
9600	96.2	175.9	0.48	8.9	165	82.1	12.7
9700	95.5	176.4	0.48	8.9	165	82.7	12.7
9800	95.3	177.9	0.48	8.9	165	82.5	12.8
9900	94.8	178.7	0.48	9.0	165	82.7	13.1
10000	94.2	179.4	0.48	9.0	165	84.2	12.9
10100	93.8	180.4	0.48	9.0	166	84.5	13.0

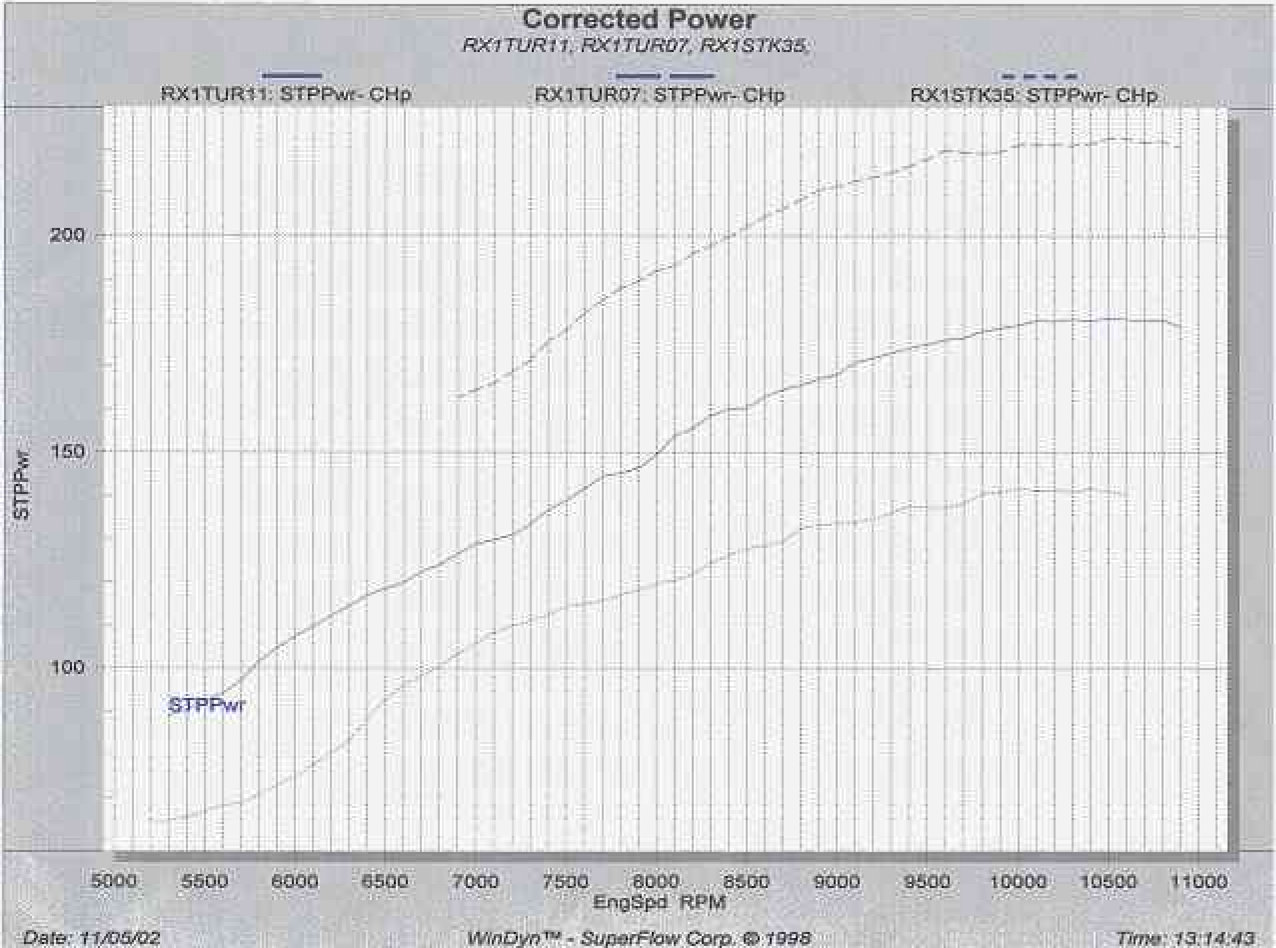
10200	92.8	180.2	0.48	9.0	166	84.4	13.1
10300	92.2	180.7	0.48	9.0	166	84.8	13.2
10400	91.0	180.3	0.50	9.0	166	87.2	12.9
10500	90.5	181.0	0.49	9.0	168	86.7	13.1
10600	89.5	180.7	0.51	9.0	168	90.0	12.6
10700	88.5	180.3	0.50	9.0	168	88.2	13.0
10800	87.8	180.5	0.51	9.0	168	89.8	12.8
10900	86.3	179.0	0.52	9.0	169	90.6	12.7

Air 2 scfm	TurboExh inletDegF	RoomAir TempDegF	Compress outletDegF	Air After 1st Inter DegF
121	744	49	125	85
120	745	49	125	85
120	746	49	125	86
120	748	49	125	86
121	750	49	125	86
123	751	49	125	86
125	755	48	125	86
128	758	49	125	86
129	761	49	125	86
133	765	48	125	87
136	770	48	125	87
140	778	48	125	88
142	784	48	125	88
144	789	48	125	89
146	796	48	125	89
148	797	49	125	90
151	808	48	126	90
155	818	48	126	91
157	821	48	126	91
159	827	48	126	91
161	832	48	126	92
164	841	49	126	92
167	844	49	126	92
170	853	50	126	92
173	860	50	126	93
177	868	49	126	94
178	869	49	126	94
182	879	49	127	94
187	884	48	127	94
189	893	48	127	94
194	904	49	128	95
195	909	50	128	95
198	915	49	128	95
201	923	50	128	96
205	931	49	129	97
208	937	50	129	97
209	944	50	129	97
212	949	50	129	98
214	956	51	130	98
216	960	50	130	98
218	965	50	130	98
222	973	49	131	99
225	981	49	131	99
228	985	49	131	100
230	993	49	132	100
231	995	49	132	100
236	1007	49	133	101
238	1008	49	133	101
240	1014	49	134	102

242	1020	48	134	103
244	1027	48	135	103
246	1031	48	136	103
247	1040	48	136	104
248	1043	48	137	104
250	1051	48	137	105
251	1054	48	138	106
252	1062	48	138	106

EngSpd RPM	STPTrq Clb-ft	STPPwr CHp	BSFC lb/hp/hr	ManPrs inHg	WtrOut degF	Fuel B lb/hr	A/F ratio	Air 2 scfm
6900	123.8	162.7	0.5	15.2	147	77.8	11.9	202
7000	123.4	164.5	0.5	15.2	148	79.3	11.7	202
7100	122.7	165.9	0.46	15.1	148	73.1	12.7	203
7200	123	168.6	0.48	15.1	148	78.4	12.1	206
7300	123.2	171.3	0.47	15.1	148	77.6	12.3	208
7400	124.7	175.7	0.49	15.5	149	81.9	11.9	214
7500	124.7	178.1	0.5	15.6	149	85	11.7	217
7600	125.8	182	0.48	15.7	149	84.7	12	221
7700	126.2	185	0.48	16	149	86	12	225
7800	126.5	187.9	0.51	16	149	91.8	11.4	229
7900	126	189.5	0.51	16	150	92.8	11.6	234
8000	126	191.8	0.5	16.2	151	93.1	11.6	235
8100	125.3	193.2	0.5	16.2	151	93.3	11.6	237
8200	125.4	195.8	0.49	16	151	93.6	11.8	241
8300	125.1	197.7	0.48	16.2	151	93.1	12.1	246
8400	124.9	199.8	0.49	16.2	152	95.9	11.8	247
8500	124.9	202.1	0.48	16.2	152	94.5	12.1	250
8600	124.9	204.5	0.48	16.1	153	97.1	12	254
8700	124.5	206.2	0.49	16.2	153	98.6	12	258
8800	124.4	208.4	0.46	16.2	153	93.8	12.8	261
8900	124.2	210.5	0.48	16.1	154	98.8	12.3	265
9000	123.3	211.3	0.49	16.2	154	101.1	12.1	268
9100	122.7	212.6	0.6	16.1	154	124.3	10	271
9200	121.9	213.5	0.6	16.2	154	125.6	10	274
9300	121.2	214.6	0.58	16.3	155	121.2	10.5	277
9400	120.8	216.1	0.55	16.4	155	116	11	279
9500	120.4	217.7	0.56	16.5	155	119.9	10.8	282
9600	120.3	219.8	0.53	16.5	155	114.2	11.4	284
9700	118.7	219.3	0.51	16.5	156	110.3	12	289
9800	117.3	218.9	0.52	16.4	156	112.5	11.8	290
9900	116.4	219.4	0.53	16.2	157	113.5	11.8	293
10000	116	220.9	0.57	16.4	158	122.7	11	294
10100	115	221.1	0.58	16.5	158	125.9	10.8	296
10200	113.7	220.9	0.56	16.6	159	121	11.3	298
10300	112.6	220.8	0.55	16.6	159	117.5	11.7	300
10400	111.7	221.2	0.53	16.6	159	114.1	12.1	301
10500	111.2	222.4	0.53	16.7	159	113.4	12.2	301
10600	110.2	222.5	0.52	16.6	159	112.1	12.4	303
10700	108.8	221.6	0.53	16.6	159	112.3	12.4	305
10800	107.9	221.8	0.53	16.6	160	113.2	12.4	306
10900	106.1	220.3	0.54	16.6	160	115.3	12.2	308

TurboExh InletDegF	Compress outDegF	airAfter1st InterDegF	airAfter2nd InterDegF	RoomAir DegF
932	103	85	47	45
943	105	86	47	45
946	106	86	47	45
954	107	87	47	45
957	108	88	47	45
966	109	89	48	45
968	110	89	48	45
977	111	90	48	45
980	112	90	48	45
988	113	91	48	45
999	115	92	48	45
1004	115	93	48	46
1009	116	93	48	47
1017	117	95	48	47
1028	119	96	48	46
1030	120	97	48	46
1038	122	97	48	46
1042	123	99	48	46
1050	124	100	49	46
1052	125	101	49	46
1061	126	102	50	46
1063	127	102	50	46
1072	128	104	50	46
1077	130	105	50	46
1081	130	106	50	45
1085	132	106	49	45
1090	132	107	48	45
1094	134	107	48	45
1100	135	109	48	45
1105	136	109	48	45
1108	137	111	49	44
1112	139	111	49	45
1116	139	112	49	45
1118	140	113	49	45
1125	141	114	51	45
1126	142	114	51	46
1133	143	115	51	47
1135	145	116	51	47
1142	146	117	51	46
1144	147	118	51	46
1152	148	119	51	46


Corrected Power
RX1TUR11, RX1TUR07, RX1STK35,
RX1TUR11: STPPwr- CHp
RX1TUR07: STPPwr- CHp
RX1STK35: STPPwr- CHp
200
150
100
STPPwr
STPPwr
5000
5500
6000
6500
7000
7500
8000
8500
9000
9500
10000
10500
11000
EngSpd RPM
Date: 11/05/02
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