Billy Howard's Ski Doo '09 ETEC 600 demonstrator

Billy Howard of Howard's Inc SkiDoo/ Arctic Cat/ Kubota/ etc in Coudersport, PA has his 600 ETEC demo running real well with his clutching and chassis setup. Since we are perplexed by the low HP of Jim Cooper's 600 ETEC tested earlier on this website, we asked Billy to bring his good runner, here for comparison. Billy is an old time DynoTecher and supreme dragracer and clutch tuner.

As we didn't expect, Billy's sled acted the same as Jim Cooper's—117 HP or less with wide variation from run to run, still three or four HP lower than the SDI 600 we ran in the Shootout last December. And still down on HP not just at peak but also throughout the powerband.

We ran about 15 full throttle dyno tests, each about 15 seconds in duration. Since the SkiDoo computer interface won't give us real time coolant temps like we get with 800s and 1000s, Billy kept excellent track of engine cylinder/ head surface/ heat exchanger temp and we documented that info on each of the dyno tests. For reference, I've included cylinder head cover surface temp measured by a Harbor Freight infrared temp gun, at the beginning of each dyno test.

We did 15 second dyno tests with head surface temps of from 60 to 130 degrees F, and HP varied from 107 to 117 not in any particular order as the following data shows! Now this engine, if it were conventional EFI or carbed, should make in my estimation 115-120 plus HP tested in this range of temps—120 plus HP at 60 deg F and maybe dropping to 115 HP at 130 deg F. I plan to try to test an SDI or carbureted engine in these temp ranges and report the results (airflow and HP).

Also during this test session I used my new $600 SuperFlow mechanical airflow meter on the engine (the original one is battered and finally quit after 20 years of abuse). This airflow information would help us possibly explain the wide variation in HP both at peak and through the midrange. I have both mechanical A/F readings (A/F A-B) and wideband Innovate (LAMAF1), which is fed from a ¼" steel tube shoved up the muffler outlet. On this engine both readings were very similar from low revs to peak revs, but different in midrange. I'm betting that the mechanical readings are more correct.

As we would find out, 90 degree head surface temp (probably 100-110 degree F coolant temp) was the "sweet spot" that gave us best fuel flow, probably best ignition timing but not the best airflow CFM (which always decreases as engine/ engine coolant temp rises).

But my initial thinking after reviewing this data is that on this engine, ETEC engine airflow may decrease more with engine temp rise than we might see with carbed or conventional EFI engines. Since this ETEC computer wont let us run powerfully at cool engine temps, where airflow is highest (as the first full sweep test shows), that might explain the lower best HP. There is perhaps a double-whammy effect here—hotter engine parts—crankcases/ crankshaft/ rods/ bearings/ piston undersides heat up incoming air, causing it to expand, and reduce net airflow CFM and HP must drop. We can see that dramatically in the graphs of HP and airflow at various engine temps, and how the HP curves mirror the airflow curves.

Why could the ETEC be worse? Gasoline absorbs heat as it vaporizes (or vapourizes) (the latent heat of vaporization). Since there is no gasoline vaporizing in the intake air in the carbs/ crankcase/ transfer port area on the ETEC, the metal parts in the crankcase may get and stay hotter, causing airflow through the engine to drop. The ETEC vaporizes all (I think) of the gasoline in the combustion chamber just prior to ignition. This is a noble thing, since it reduces compressed charge temp in the chamber thus reducing the likelihood of detonation. But that heat of vaporization would seem to have the same eventual effect on peak combustion chamber temp whether the vaporization occurs in the crankcase or in the combustion chamber (though ultimate peak temp might be higher on non-ETEC 600s if their net airflow and actual operating compression is higher). But ETEC fuel vaporization might do little to help airflow into the crankcase since all of this heat absorption happens after the transfer ports are closed!

This makes sense, but before you think I'm a smart guy I have to say this supposition came from Kevin Cameron who suggested airflow may be low because of the ETEC fuel system (and/ or could port size/ timing be different?). KC is a great resource for us (even though he's only ridden a snowmobile once). When I encounter strangeness (which is often) I have the benefit of his experience to help try to figure things out. We are privileged to have his ongoing input.

Kevin is surprised by the high BSFC at peak revs. A/F ratio at peak revs is not ETEC-like lean, but more conventional 12/1, which we would expect would create BSFC a full tenth lower. That remains mysterious, and we hope that when Jim Cooper gets his reflash it will be leaner, and more powerful with accompanying lower BSFC.

Now even though peak ETEC HP so far is lower than SDI or carbed 600s, the midrange A/F ratio and BSFC is excellent, four-stroke-like. On Billy's sled we tested partials after exhaust valve opening at 5900 and 6700 and BSFC is in the low .40 lb/hphr range. Here, I set the SuperFlow dyno computer to hold engine speed constant, and took random data samples as throttle was gradually opened from fast idle to WOT. Note HP and airflow, and estimate throttle position, and estimate the HP necessary to operate the sled at various speeds on the lakes/ trails. Part throttle BSFC is low, but becomes more conventional as throttle approaches WOT.

We'll begin the test data on Billy's ETEC 600 with the part throttle data, created at about 100 degree F cylinder head temp:

Part to full throttle test, 5900 RPM steady state

EngSpd	STPTrq	STPPwr	BSFA-B	FulA-B	AirTmp	Air 2	LAMAF1	A/FA-B
RPM	Clb-ft	CHp	lb/hph	lb/hr	degF	scfm	Ratio	Ratio
5928	40.8	46.0	0.44	19.9	41	77	15.0	17.69
5948	45.6	51.7	0.44	22.0	40	85	14.5	17.77
5912	47.7	53.7	0.49	25.5	40	90	14.3	16.14
5922	50.7	57.1	0.48	27.0	39	99	14.3	16.75

5916	55.5	62.6	0.50	30.5	40	112	14.6	16.81
5915	60.7	68.4	0.52	34.8	40	129	14.6	16.96
5870	63.5	70.9	0.56	38.6	41	139	14.9	16.49

Part to full throttle test, 6700 RPM steady state

EngSpd	STPTrq	STPPwr	BSFA-B	FulA-B	AirTmp	Air1+2	LAMAF1	A/FA-B
RPM	Clb-ft	CHp	lb/hph	lb/hr	degF	scfm	Ratio	Ratio
6693	48.1	61.2	0.44	26.1	39	101	14.2	17.66
6780	52.2	67.4	0.45	29.8	40	110	14.1	16.85
6710	53.1	67.9	0.47	30.9	40	111	14.3	16.50
6762	57.1	73.5	0.47	33.8	40	121	14.4	16.35
6735	58.5	75.0	0.50	36.6	39	127	14.4	15.92
6716	60.9	77.8	0.56	42.6	40	137	14.2	14.71
6660	61.2	77.5	0.64	48.2	41	141	13.7	13.44
6686	61.2	77.9	0.65	49.6	40	146	13.5	13.50
6683	60.6	77.2	0.64	47.8	41	148	13.6	14.22
6711	60.9	77.9	0.62	47.3	41	150	13.6	14.49
6704	62.0	79.1	0.62	48.0	40	154	13.9	14.71
6693	62.1	79.2	0.62	48.1	39	157	14.3	14.93

Here is a series of full throttle sweep tests, from coolest to hottest head surface temp. Note that in our coolest test we had best midrange airflow and HP with rich fuel flow but unfortunately HP dropped suddenly at 7400 before we reached the peak revs (this was surely on its way to 120 plus HP before the ECU cut our fun short. Note that on that cool engine 60 degree run, airflow CFM dropped as suddenly as HP—**does the ECU cause exhaust valves to shut at that speed with cool coolant?** Those rascal engineers at SkiDoo may be spoiling our cool-engine fun.

Begin test with 60 degree F head temp (best midrange airflow CFM but mysteriously dropped after 7400 RPM)

EngSpd	STPTrq	STPPwr	BSFA-B	FulA-B	AirTmp	Air 2	LAMAF1	A/FA-B
RPM	Clb-ft	CHp	lb/hph	lb/hr	degF	scfm	Ratio	Ratio
5400	60.3	62.0	0.62	37.4	40	121	15.6	14.86
5500	61.0	63.9	0.62	39.0	40	125	15.4	14.71
5600	61.9	66.0	0.61	39.6	39	130	15.2	15.07
5700	63.4	68.8	0.62	41.7	40	135	15.1	14.86
5800	63.7	70.3	0.61	41.8	40	139	14.9	15.27
5900	64.7	72.7	0.67	47.3	40	145	14.4	14.06
6000	64.7	73.9	0.67	48.2	42	148	14.2	14.03
6100	65.9	76.5	0.68	50.9	40	154	14.0	13.86
6200	66.2	78.1	0.65	49.8	40	157	13.8	14.41
6300	67.2	80.6	0.66	52.3	40	160	13.8	14.02
6400	67.5	82.3	0.65	51.9	40	162	13.9	14.29
6500	67.8	83.9	0.66	54.0	39	166	13.8	14.08
6600	62.3	78.3	0.67	51.1	39	160	14.3	14.33
6700	62.3	79.5	0.66	51.6	39	160	14.3	14.19
6800	63.5	82.2	0.65	52.2	39	162	14.4	14.18
6900	68.2	89.7	0.62	54.6	39	168	14.3	14.11
7000	70.8	94.4	0.65	60.3	39	174	13.9	13.25

7100	71.1	96.1	0.67	63.3	39	177	13.6	12.84
7200	72.1	98.9	0.65	63.3	39	181	13.4	13.10
7300	74.7	103.8	0.68	69.4	40	188	12.9	12.38
7400	75.7	106.6	0.70	73.0	40	192	12.4	12.07
7500	60.0	85.7	0.83	69.8	39	183	12.1	11.98
7600	60.5	87.6	0.82	70.0	39	184	12.1	12.07
7700	61.1	89.6	0.8	70.2	39	186	12.1	12.15

Begin test with 77 degree F head temp (fuel A is gross fuel pump capacity)

EngSpd	STPTrq	STPPwr	BSFA-B	FulA-B	Fuel A	Air1+2	LAMAF1	A/FA-B
RPM	Clb-ft	CHp	lb/hph	lb/hr	lb/hr	scfm	Ratio	Ratio
4800	43.0	39.3	0.67	25.6	129.4	93	16.1	16.67
4900	44.4	41.4	0.73	29.3	130.1	95	15.8	14.87
5000	44.4	42.2	0.71	29.1	130.3	96	15.7	15.06
5100	48.4	47.0	0.67	30.3	129.5	99	15.1	14.97
5200	52.3	51.8	0.63	31.5	129.5	106	14.8	15.43
5300	52.3	52.8	0.63	32.1	129.8	107	14.7	15.29
5400	55.9	57.5	0.57	31.7	129.6	114	14.8	16.51
5500	57.8	60.5	0.58	33.8	130.4	118	14.9	15.98
5600	58.2	62.1	0.57	34.5	129.5	122	15.1	16.19
5700	61.1	66.3	0.57	36.5	127.9	130	15.1	16.36
5800	62.3	68.8	0.56	37.4	128.4	135	15.0	16.51
5900	63.4	71.2	0.61	42.2	130.7	140	14.7	15.19
6000	63.6	72.7	0.58	40.8	129.5	144	14.5	16.15
6100	64.8	75.2	0.63	46.3	131.5	149	14.1	14.75
6200	64.8	76.5	0.63	46.9	132.1	151	14.0	14.71
6300	67.0	80.4	0.60	47.1	131.2	155	14.1	15.08
6400	67.6	82.3	0.58	46.7	130.6	158	14.2	15.46
6500	66.8	82.7	0.60	47.8	131.4	160	14.5	15.32
6600	57.7	72.5	0.62	43.9	131.0	152	15.1	15.81
6700	57.6	73.5	0.61	43.5	130.6	152	15.2	15.99
6800	58.5	75.7	0.61	45.0	130.5	154	15.3	15.66
6900	65.9	86.6	0.65	54.3	131.3	163	14.7	13.72
7000	66.5	88.7	0.62	53.0	130.0	164	14.5	14.20
7100	67.7	91.5	0.63	56.0	130.9	169	14.2	13.78
7200	68.8	94.4	0.61	56.3	131.4	172	14.1	14.03
7300	72.2	100.4	0.65	63.8	133.6	180	13.6	12.91
7400	75.0	105.7	0.64	66.0	133.3	187	13.0	12.94
7500	75.5	107.8	0.64	67.2	133.2	189	12.9	12.88
7600	77.6	112.2	0.65	70.9	135.3	195	12.7	12.62
7700	77.3	113.3	0.66	72.8	135.0	199	12.5	12.51
7800	77.7	115.4	0.69	76.9	136.1	205	12.3	12.20
7900	77.4	116.4	0.70	79.1	136.6	207	12.1	11.98
8000	76.6	116.6	0.72	81.2	136.8	212	12.0	11.94
8100	74.6	115.1	0.72	80.4	135.8	213	12.1	12.11
8200	70.2	109.6	0.74	79.1	135.6	212	12.3	12.25

Begin test with 80 degree F head temp

EngSpd	STPTrq	STPPwr	BSFA-B	FulA-B	AirTmp	Air1+2	LAMAF1	A/FA-B
RPM	Clb-ft	CHp	lb/hph	lb/hr	degF	scfm	Ratio	Ratio
4900	48.4	45.1	0.65	28.4	44	96	16.6	15.51
5000	48.6	46.2	0.63	28.3	44	97	16.4	15.63
5100	52.4	50.8	0.65	32.0	44	102	15.9	14.62
5200	52.9	52.4	0.64	32.3	44	104	15.8	14.71
5300	55.1	55.6	0.62	33.7	44	110	15.7	14.94
5400	57.9	59.6	0.55	32.1	43	117	15.8	16.71
5500	58.5	61.2	0.56	33.6	43	120	15.8	16.35
5600	60.9	64.9	0.53	33.7	44	126	15.9	17.13
5700	60.9	66.1	0.55	35.0	44	128	16.0	16.77
5800	63.0	69.6	0.56	37.7	43	135	15.8	16.44
5900	64.3	72.3	0.56	39.5	43	142	15.3	16.47
6000	64.7	73.9	0.60	42.9	42	146	15.0	15.54
6100	65.1	75.6	0.61	44.6	42	149	14.8	15.35
6200	67.1	79.2	0.62	47.9	42	154	14.4	14.68
6300	66.7	80.0	0.64	50.0	42	155	14.3	14.17
6400	67.8	82.6	0.61	48.8	43	159	14.2	14.92
6500	67.6	83.6	0.59	48.3	41	163	14.5	15.48
6600	59.5	74.7	0.63	45.5	42	155	15.1	15.61
6700	59.6	76.0	0.64	47.5	42	156	15.2	15.02
6800	61.3	79.4	0.62	47.7	41	158	15.3	15.18
6900	65.6	86.2	0.62	52.1	42	163	15.2	14.37
7000	68.3	91.0	0.61	54.2	42	167	14.6	14.14
7100	70.0	94.7	0.63	57.9	42	172	14.4	13.59
7200	72.2	98.9	0.62	60.1	42	179	13.9	13.60
7300	72.5	100.8	0.62	61.0	42	180	13.7	13.52
7400	75.9	106.9	0.64	66.6	41	189	13.2	12.96
7500	76.2	108.8	0.66	70.3	42	192	12.8	12.52
7600	77.3	111.9	0.67	73.3	42	199	12.6	12.41
7700	77.3	113.4	0.69	75.7	42	201	12.4	12.14
7800	77.1	114.6	0.71	78.7	41	206	12.2	11.97
7900	75.7	113.8	0.74	81.9	42	210	11.8	11.74
8000	74.5	113.4	0.74	81.8	41	212	11.7	11.85
8100	72.3	111.5	0.74	80.5	43	211	11.8	12.01

Begin test with 90 degree F head temp (this was sweet spot with lean fuel flow)

EngSpd	STPTrq	STPPwr	BSFA-B	FulA-B	AirTmp	Air1+2	LAMAF1	A/FA-B
RPM	Clb-ft	CHp	lb/hph	lb/hr	degF	scfm	Ratio	Ratio
5100	44.0	42.7	0.64	26.8	37	96	16.5	16.42
5200	44.0	43.5	0.61	26.0	37	96	16.5	16.99
5300	45.1	45.5	0.59	26.2	37	98	16.4	17.18
5400	53.5	55.0	0.54	29.3	37	112	16.2	17.58
5500	53.7	56.3	0.56	30.7	37	114	16.2	17.07
5600	56.5	60.2	0.53	31.2	37	122	16.5	17.90
5700	56.7	61.5	0.54	32.3	37	124	16.5	17.63
5800	60.1	66.4	0.56	36.3	36	132	16.4	16.65
5900	61.3	68.9	0.56	37.5	36	136	16.0	16.60
6000	61.6	70.4	0.56	38.4	37	139	15.7	16.60

6100	63.6	73.9	0.54	39.0	38	145	15.1	17.06
6200	63.3	74.7	0.56	40.6	38	147	14.9	16.60
6300	64.4	77.3	0.57	42.9	38	150	14.8	16.05
6400	64.6	78.8	0.58	44.3	38	154	14.8	15.88
6500	55.1	68.2	0.60	39.9	37	151	15.7	17.30
6600	54.5	68.5	0.60	40.0	37	151	15.8	17.28
6700	54.7	69.8	0.61	41.5	37	151	15.9	16.66
6800	58.8	76.1	0.63	46.9	37	151	16.1	14.77
6900	60.2	79.1	0.62	48.0	37	154	15.5	14.67
7000	60.6	80.8	0.60	47.7	37	155	15.3	14.90
7100	61.5	83.1	0.61	49.5	38	160	14.6	14.76
7200	63.1	86.6	0.60	50.7	38	163	14.5	14.71
7300	67.2	93.5	0.64	58.8	37	171	13.7	13.31
7400	69.6	98.0	0.64	61.7	37	178	13.4	13.19
7500	69.9	99.8	0.65	63.2	37	181	13.1	13.13
7600	70.8	102.5	0.63	63.3	37	184	13.0	13.30
7700	74.4	109.0	0.66	70.0	37	192	12.6	12.59
7800	75.3	111.8	0.65	71.2	38	196	12.4	12.60
7900	76.0	114.3	0.68	76.1	40	201	12.0	12.10
8000	75.5	115.0	0.69	77.3	39	202	12.0	11.99
8100	75.7	116.7	0.67	76.2	39	206	12.0	12.38
8200	74.4	116.1	0.67	76.7	37	209	12.2	12.47
8300	72.2	114.2	0.67	75.0	37	210	12.4	12.84
8400	70.3	112.4	0.68	74.2	38	210	12.5	12.94

Begin test with 130 degree F head temp (note lowest airflow CFM)

EngSpd	STPTrq	STPPwr	BSFA-B	FulA-B	AirTmp	Air 2	LAMAF1	A/FA-B
RPM	Clb-ft	CHp	lb/hph	lb/hr	degF	scfm	Ratio	Ratio
5100	40.5	39.3	0.75	28.8	38	92	14.5	14.69
5200	40.5	40.1	0.74	28.9	38	93	14.5	14.67
5300	41.1	41.4	0.73	29.6	38	94	14.4	14.48
5400	48.6	49.9	0.67	31.4	37	94	14.1	13.70
5500	50.5	52.9	0.67	32.9	37	97	14.1	13.50
5600	57.0	60.8	0.60	34.0	37	109	14.2	14.68
5700	59.9	65.0	0.56	33.4	39	110	14.3	15.08
5800	58.3	64.4	0.57	35.2	38	122	14.2	15.92
5900	58.0	65.1	0.59	37.1	38	128	14.2	15.76
6000	58.0	66.3	0.66	42.6	41	135	13.8	14.51
6100	59.3	68.9	0.65	44.0	39	141	13.4	14.68
6200	60.2	71.1	0.64	44.2	39	144	13.3	14.96
6300	60.5	72.6	0.65	45.9	39	147	13.3	14.71
6400	62.1	75.7	0.63	46.5	38	150	13.5	14.78
6500	63.0	78.0	0.63	47.6	39	153	13.8	14.72
6600	53.2	66.8	0.70	45.8	39	144	14.2	14.40
6700	53.6	68.4	0.69	46.2	39	144	14.4	14.23
6800	54.6	70.7	0.68	46.8	39	145	14.4	14.22
6900	58.6	77.0	0.69	51.4	40	151	14.2	13.44
7000	59.5	79.3	0.70	54.4	39	154	13.8	12.98
7100	61.1	82.6	0.70	56.3	38	160	13.4	13.00
7200	62.9	86.2	0.71	59.9	37	166	13.1	12.67
7300	64.3	89.3	0.71	62.4	37	171	12.7	12.54

7400	64.3	90.5	0.73	64.9	37	174	12.2	12.25
7500	64.3	91.8	0.73	65.2	37	175	12.1	12.32
7600	64.6	93.4	0.70	64.4	37	178	12.1	12.67
7700	68.2	100.0	0.72	70.4	38	188	11.6	12.26
7800	69.4	103.0	0.74	74.3	37	195	11.5	12.04
7900	68.9	103.6	0.77	77.8	37	199	11.3	11.69
8000	69.4	105.7	0.75	77.6	37	200	11.2	11.80
8100	70.0	107.9	0.76	79.7	38	203	11.3	11.68
8200	66.0	103.1	0.80	80.7	37	208	11.4	11.8

Here is final key graph, most notable Airflow VS HP comparison. Airflow = Horsepower Also note that green 90 degree is leanest fuel flow, causes pipe temp to climb (hot pipe also reduces airflow CFM), and HP peak to higher revs, peaking at 8100-8200 RPM.