2017 Arctic Cat XF 9000 Thundercat turbo production sled

Billy Howard, owner of Howard's Inc SkiDoo/ Arctic Cat in Coudersport, PA brought this almost-new (40 miles of WOT grass and asphalt testing/ bracket racing at the AmSnow Shootout in MI) TCat for typical out-of-the-crate evaluation. Since Howard's is now a Speedwerx distributor he had with him a new Speedwerx prototype stainless steel lightweight muffler for dyno testing.

Our initial dyno testing was done with 93.5 octane R+M/2 zero ethanol fuel--similar to the fuel used in our Yamaha Sidewinder test we did late last winter (posted here on 3/16/15). Billy also brought along some 93 octane ethanol fuel to test with, to see what would result from the ethanol's added O2 and increased density of the charge air from the higher heat of vaporization.

Since we didn't tap into the new sled's cooling system, we did just two back-to-back tests--each first WARM test was begun at 155F coolant temp and ended just over 170F (charge air temp peaked @110F as we directed 80mph rooftop blower air at the intercooler). Then each second HOT test would be run immediately afterwards at @180-195F and charge air would measure @120F. All of this internal temp info was monitored by Billy's new Catt II Arctic Cat diagnostic equipment. Interestingly, with the stock muffler we made best HP on the first warm test then it would drop about 4 HP. But with the Speedwerx muffler we always made best HP on the second hot test!

Beginning with non-ethanol fuel, the dyno results of this production TCat was very similar to the Sidewinder demo sled tested last March--and a few less HP than the TCat that Tom Ferry of Arctic Adventures brought here for testing (posted here 6/12/16). This appears to be due to this production TCat's richer (safer) A/F ratio, and perhaps on-boost timing that's retarded a degree or two. But great power, nonetheless!

Beginning with the 93.5 octane non-ethanol fuel, here is a typical test on the first warm test ending at 171F coolant and 110F charge air temp. Note the declining fuel flow lb/hr just beyond the peak HP RPM. Also airflow CFM is shown as LM1air--a mathematical function of measured fuel flow and wideband A/F.

2017 XF9000 stock muffler non-ethanol fuel

EngSpd RPM	STPPwr CHp	STPTrq Clb-ft	BSFA_B lb/hph	FulA_B lbs/hr	LamAF1 Ratio	BoostP psig	LM1Air SCFM
6500	159.1	128.5	0.446	66.1	12.4	8.4	189
6600	160.0	127.3	0.447	66.6	12.3	8.4	189
6700	161.0	126.2	0.447	67.0	12.2	8.4	189
6800	162.3	125.4	0.446	67.5	12.2	8.5	189
6900	163.8	124.7	0.447	68.2	12.1	8.5	190
7000	165.5	124.2	0.449	69.2	12.0	8.6	192
7100	167.1	123.6	0.452	70.3	12.0	8.7	195
7200	169.2	123.4	0.455	71.6	12.0	8.9	198

7300	172.5	124.1	0.456	73.2	12.0	9.3	202
7400	177.0	125.6	0.454	74.8	12.0	9.7	207
7500	181.9	127.4	0.451	76.4	12.0	10.0	211
7600	185.7	128.3	0.450	77.9	12.0	10.0	215
7700	187.6	127.9	0.455	79.4	11.9	10.0	218
7800	188.4	126.9	0.461	80.8	11.9	10.0	222
7900	190.0	126.3	0.465	82.1	11.9	10.1	224
8000	192.4	126.3	0.465	83.3	11.8	10.2	227
8100	194.2	125.9	0.466	84.1	11.8	10.2	229
8200	195.3	125.1	0.466	84.6	11.8	10.2	231
8300	196.5	124.3	0.465	84.9	11.9	10.2	233
8400	198.6	124.2	0.463	85.4	12.0	10.3	235
8500	200.8	124.1	0.461	86.0	12.0	10.3	238
8600	202.6	123.8	0.460	86.7	12.1	10.3	241
8700	203.8	123.1	0.461	87.3	12.1	10.3	243
8800	204.2	121.9	0.462	87.6	12.1	10.3	244
8900	203.2	119.9	0.461	86.9	12.2	10.4	244
9000	201.3	117.5	0.455	85.0	12.5	10.4	244
9100	197.1	113.8	0.443	81.0	13.0	10.6	242
9200	189.3	108.1	0.437	76.8	13.5	10.6	239

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Here is the stock XF9000 tested with ethanol fuel. The fuel Billy brought in a jug tested at just over 7% so we added just enough E85 fuel to bring it up to 9.9% (and 93.6 octane R+M/2). Note the slight increase in airflow due to a combination of added O2 and denser charge air in the combustion chambers.

2017 XF9000 stock muffler 9.9% ethanol fuel

EngSpd RPM	STPPwr CHp	STPTrq Clb-ft	BSFA_B lb/hph	FulA_B lbs/hr	LamAF1 Ratio	BoostP psig	LM1Air SCFM
6500	159.9	129.2	0.443	65.7	12.71	8.3	194
6600	161.0	128.1	0.443	66.2	12.63	8.4	194
6700	162.0	127.0	0.444	66.7	12.55	8.4	194
6800	163.4	126.2	0.443	67.1	12.48	8.5	194
6900	165.0	125.6	0.442	67.7	12.44	8.5	195
7000	166.5	124.9	0.444	68.7	12.41	8.5	198
7100	168.0	124.3	0.447	69.7	12.40	8.6	200
7200	170.3	124.2	0.447	70.7	12.39	8.9	203
7300	173.8	125.0	0.445	71.7	12.39	9.3	206
7400	178.4	126.6	0.441	72.9	12.38	9.6	209
7500	182.7	127.9	0.439	74.4	12.37	9.8	213
7600	185.6	128.2	0.440	75.8	12.35	9.8	217

7700	187.5	127.9	0.443	77.1	12.32	9.8	220
7800	188.9	127.2	0.446	78.2	12.28	10.0	223
7900	191.4	127.2	0.447	79.4	12.25	10.2	225
8000	194.1	127.4	0.448	80.6	12.22	10.2	229
8100	195.6	126.8	0.451	81.7	12.23	10.1	232
8200	196.4	125.8	0.453	82.4	12.25	10.1	234
8300	198.0	125.3	0.453	83.1	12.29	10.2	237
8400	200.4	125.3	0.451	83.8	12.33	10.2	240
8500	202.4	125.0	0.451	84.5	12.37	10.2	242
8600	203.9	124.6	0.451	85.1	12.40	10.2	245
8700	205.0	123.7	0.451	85.5	12.44	10.2	247
8800	205.3	122.5	0.450	85.5	12.53	10.2	248
8900	203.6	120.1	0.447	84.3	12.68	10.3	248
9000	201.0	117.3	0.438	81.5	12.98	10.4	245
9100	197.6	114.0	0.429	78.3	13.29	10.5	241
9200	191.3	109.2	0.425	75.2	13.60	10.5	237

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Here is the prototype Speedwerx stainless steel muffler version tested with both non-ethanol and 9.9% ethanol fuel. The 10+% increase in airflow was combined with stock fuel flow *and* higher boost pressure to increase HP by 24-25! Too much? Probably, if fuel flow is unaltered. The resulting leaner mixture puts the engine right at max HP A/F ratio at peak HP RPM, with little unburned fuel to vaporize and absorb heat to help cool combustion chambers. Note that the slightly declining top end fuel flow lb/hr results in A/F ratio leaning out as revs climb. Running out of "gear" on top end might allow revs to climb toward the rev limiter (just over 9200) where A/F ratio is a very lean 14.5/1 with ethanol fuel. Every hotrodder's TCat should be fitted with a wideband digital A/F gauge (harping again!). As this is posted, Speedwerx has a Thundercat engine on their SuperFlow engine dyno, and perhaps they'll add some restriction to the SS muffler to maintain richer A/F ratio at peak revs.

As mentioned earlier, when fitted with the higher flowing Speedwerx muffler the boost pressure increased noticeably compared to stock--especially at low revs and high revs. I spoke to Sean Ray about this (now Engine Performance Test Leader on the Ford Racing V6 turbo program at Roush Yates) and we're surmising that the higher exhaust flow is exceeding the standard flow capacity of the wastegate. It's possible that at low revs from clutch engagement to midrange the wastegate controller is programmed to hold the wastegate fixed in a partially open position to cause boost to increase gradually as revs climb--otherwise the tiny ball bearing turbo would be at 10 psi from clutch engagement to max revs (the way most of us would surely like it!). But as we can see in the graphs it looks like the Speedwerx muffler causes boost to climb hard against the partially open wastegate--then when the ECU sees 10+ PSI it dumps to wide open--boost drops at 7000 with wastegate as open as possible. Then boost climbs even with wastegate as open as possible as revs climb. Remember--the wastegate is forced open by a combination of charge pressure on the controller diaphragm *and* exhaust pressure on the internal metal valve itself. And note how airflow and HP climb with the hotter engine. Could this be due to the heat soaked exhaust manifold/ turbine housing resulting in more heat energy left to spin the turbine wheel harder? Sean suggested that we're lacking important data--exhaust backpressure and turbine inlet temp. When someone comes to DTR to tune and improved/ prostock Sidewinder/ Thundercat we'll try to get that data. For now, note in the following graph of airflow comparing warm and hot tests with both stock and Speedwerx muffler that the wastegate controls boost pressure/ airflow perfectly with stock muffler, but seems to lose control with the

Here is the dyno test data with the Speedwerx muffler with both non ethanol and 9.9% ethanol fuel.

2017 XF9000 Speedwerx prototype muffler non-ethanol fuel

EngSpd	STPPwr	STPTrq	BSFA_B	FulA_B	LamAF1	BoostP	LM1Air
RPM	CHp	Clb-ft	lb/hph	lbs/hr	Ratio	psig	SCFM
6500	175.1	141.5	0.423	68.8	12.90	10.0	206
6600	177.6	141.3	0.426	70.3	12.84	10.1	209
6700	180.1	141.2	0.428	71.7	12.77	10.3	212
6800	182.8	141.2	0.430	72.9	12.71	10.4	215
6900	185.4	141.1	0.428	73.7	12.66	10.5	216
7000	188.3	141.3	0.425	74.3	12.63	10.7	217
7100	190.7	141.1	0.421	74.5	12.61	10.6	218
7200	191.4	139.6	0.420	74.7	12.59	10.3	218
7300	191.7	137.9	0.421	75.0	12.58	10.1	219
7400	192.1	136.3	0.422	75.3	12.57	10.0	219
7500	193.3	135.4	0.423	75.8	12.54	10.1	220
7600	195.6	135.2	0.422	76.6	12.52	10.2	222
7700	198.2	135.2	0.422	77.6	12.49	10.3	224
7800	200.5	135.0	0.424	78.9	12.46	10.3	228
7900	202.5	134.6	0.427	80.2	12.42	10.3	231
8000	204.9	134.5	0.429	81.5	12.40	10.3	234
8100	207.4	134.5	0.430	82.6	12.41	10.4	238
8200	210.1	134.6	0.430	83.8	12.45	10.5	242
8300	213.1	134.9	0.430	85.0	12.52	10.6	246
8400	216.5	135.4	0.429	86.1	12.59	10.7	251
8500	219.7	135.8	0.427	87.0	12.67	10.8	255
8600	222.6	136.0	0.425	87.7	12.75	10.9	259
8700	225.3	136.0	0.423	88.3	12.83	11.0	262
8800	227.3	135.7	0.420	88.5	12.96	11.1	266
8900	228.3	134.7	0.415	87.9	13.17	11.2	268
9000	227.1	132.5	0.409	86.0	13.54	11.3	270
9100	221.9	128.1	0.408	83.9	13.91	11.6	270
9200	212.6	121.4	0.415	81.7	14.28	12.0	270

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2017 XF9000 Speedwerx prototype muffler 9.9% ethanol fuel

EngSpd RPM	STPPwr CHp	STPTrq Clb-ft	BSFA_B lb/hph	FulA_B lbs/hr	LamAF1 Ratio	BoostP psig	LM1Air SCFM
6500	176.0	142.2	0.424	69.3	13.23	10.8	212
6600	178.1	141.8	0.426	70.4	13.17	10.9	215
6700	181.0	141.9	0.425	71.4	13.12	11.0	217
6800	184.2	142.3	0.423	72.2	13.07	11.1	219
6900	187.1	142.4	0.420	72.9	13.03	11.3	220
7000	189.9	142.5	0.416	73.4	13.00	11.4	221
7100	192.3	142.3	0.414	73.9	12.97	11.2	222
7200	193.1	140.8	0.415	74.4	12.96	10.9	223
7300	192.8	138.7	0.419	74.9	12.94	10.6	225
7400	193.2	137.1	0.422	75.6	12.92	10.6	226
7500	194.5	136.2	0.423	76.3	12.90	10.6	228
7600	196.6	135.9	0.424	77.2	12.87	10.7	230
7700	199.4	136.0	0.423	78.3	12.84	10.8	233
7800	202.2	136.2	0.424	79.4	12.80	10.8	235
7900	204.7	136.1	0.425	80.5	12.76	10.9	238
8000	206.8	135.8	0.425	81.5	12.74	10.9	241
8100	209.1	135.6	0.425	82.3	12.75	10.9	243
8200	211.9	135.7	0.423	83.1	12.80	11.0	246
8300	215.3	136.3	0.420	83.8	12.86	11.1	250
8400	218.8	136.8	0.417	84.5	12.95	11.2	253
8500	222.1	137.2	0.414	85.1	13.04	11.3	257
8600	224.8	137.3	0.413	85.9	13.12	11.4	261
8700	227.0	137.0	0.412	86.5	13.22	11.5	265
8800	229.2	136.8	0.409	86.7	13.36	11.6	268
8900	230.4	136.0	0.403	85.9	13.55	11.7	270
9000	229.2	133.7	0.395	83.7	13.89	11.9	269
9100	224.6	129.6	0.392	81.4	14.24	12.2	269
9200	213.6	121.9	0.402	79.3	14.58	12.5	268

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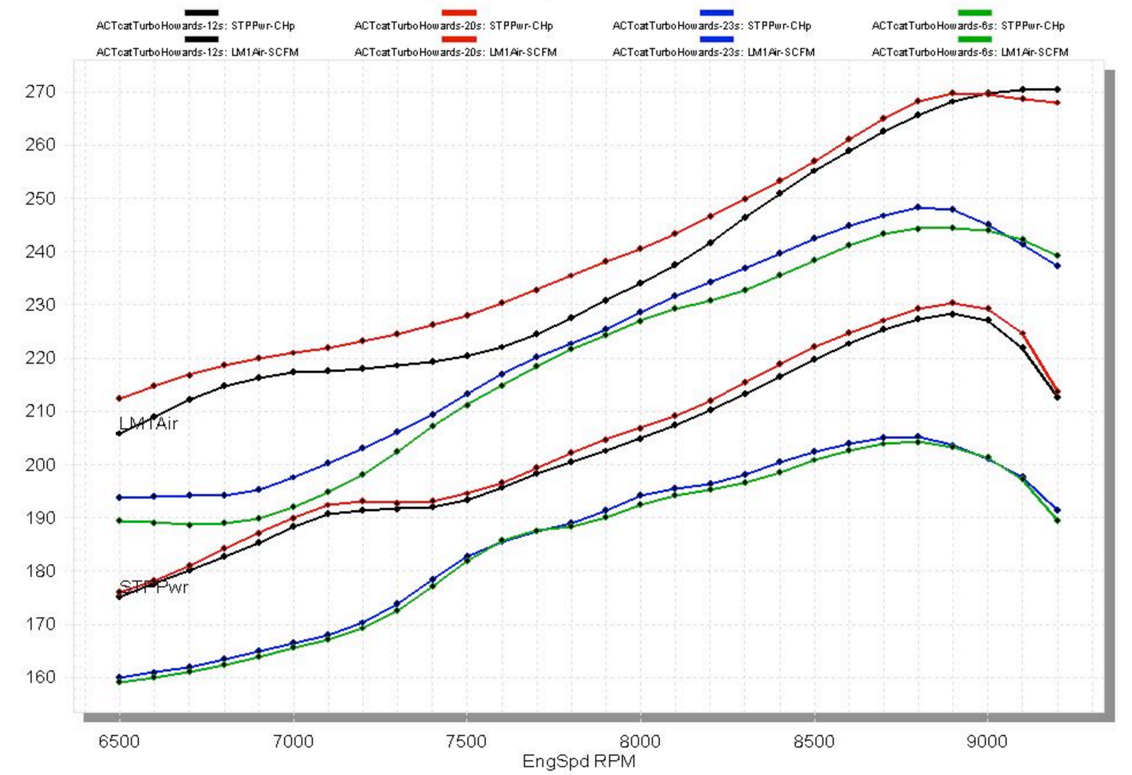
Effect of reduced backpressure and ethanol on airflow and HP

Green stock noneth, Blue stock eth, Black SWmuf noneth, Red SWmuf eth



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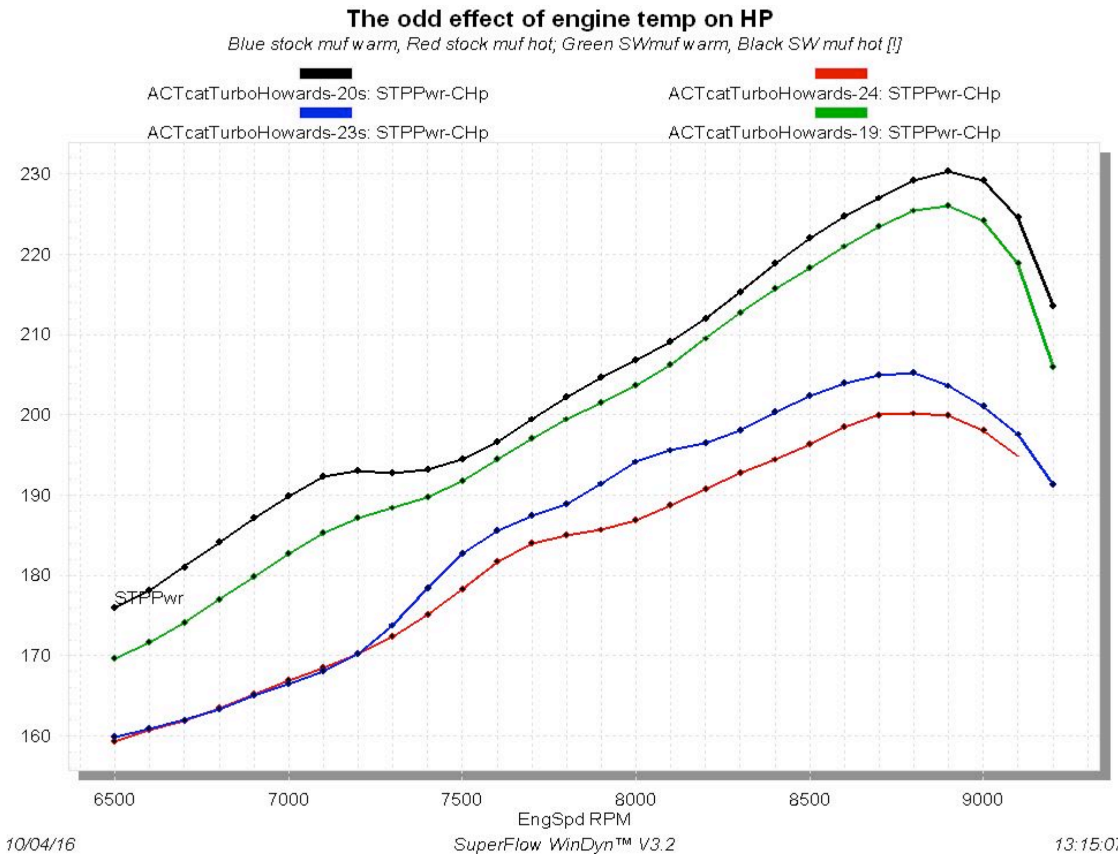
The odd effect of engine temp on HP
Blue stock muf warm, Red stock muf hot; Green SWmuf warm, Black SW muf hot [!]
ACTcatTurboHowards-20s: STPPwr-CHp
ACTcatTurboHowards-24: STPPwr-CHp
ACTcatTurboHowards-23s: STPPwr-CHp
ACTcatTurboHowards-19: STPPwr-CHp
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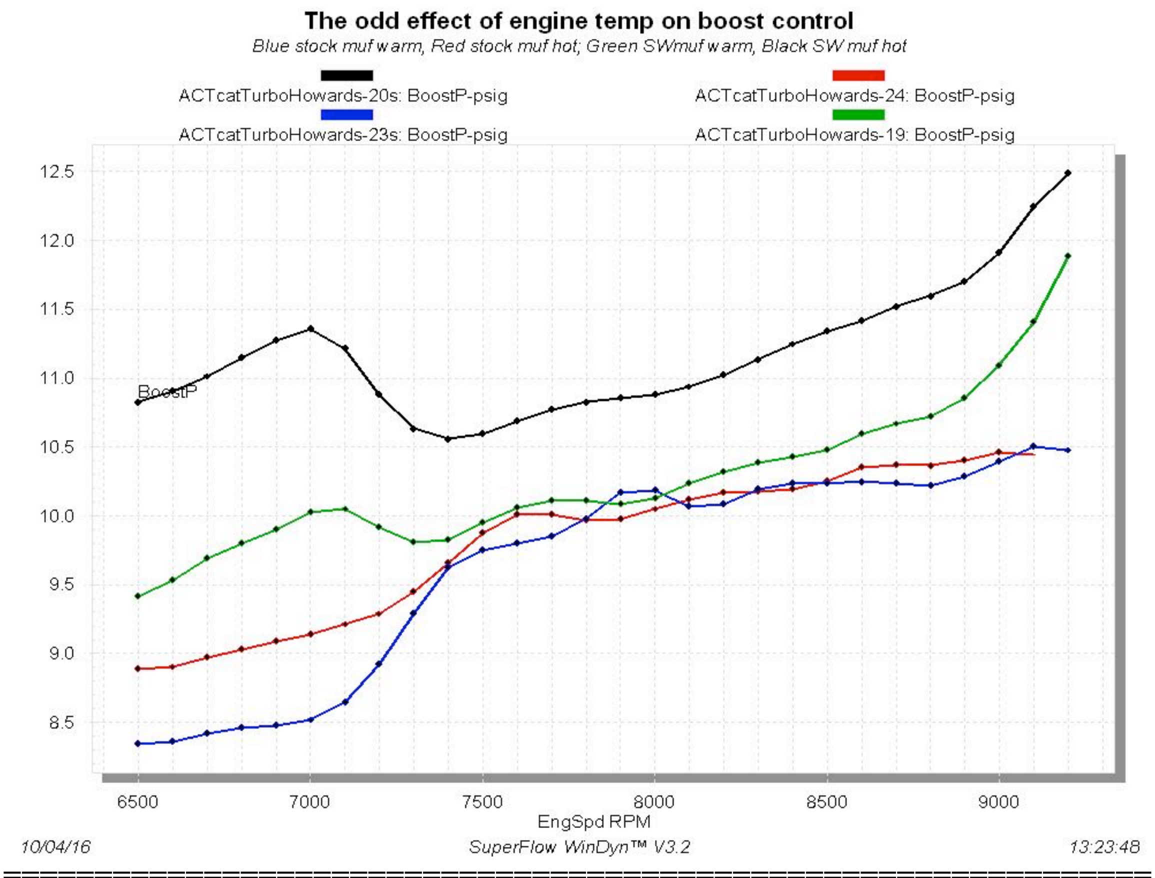
The odd effect of engine temp on boost control
Blue stock muf warm, Red stock muf hot; Green SWmuf warm, Black SW muf hot
ACTcatTurboHowards-20s: BoostP-psig
ACTcatTurboHowards-24: BoostP-psig
ACTcatTurboHowards-23s: BoostP-psig
ACTcatTurboHowards-19: BoostP-psig
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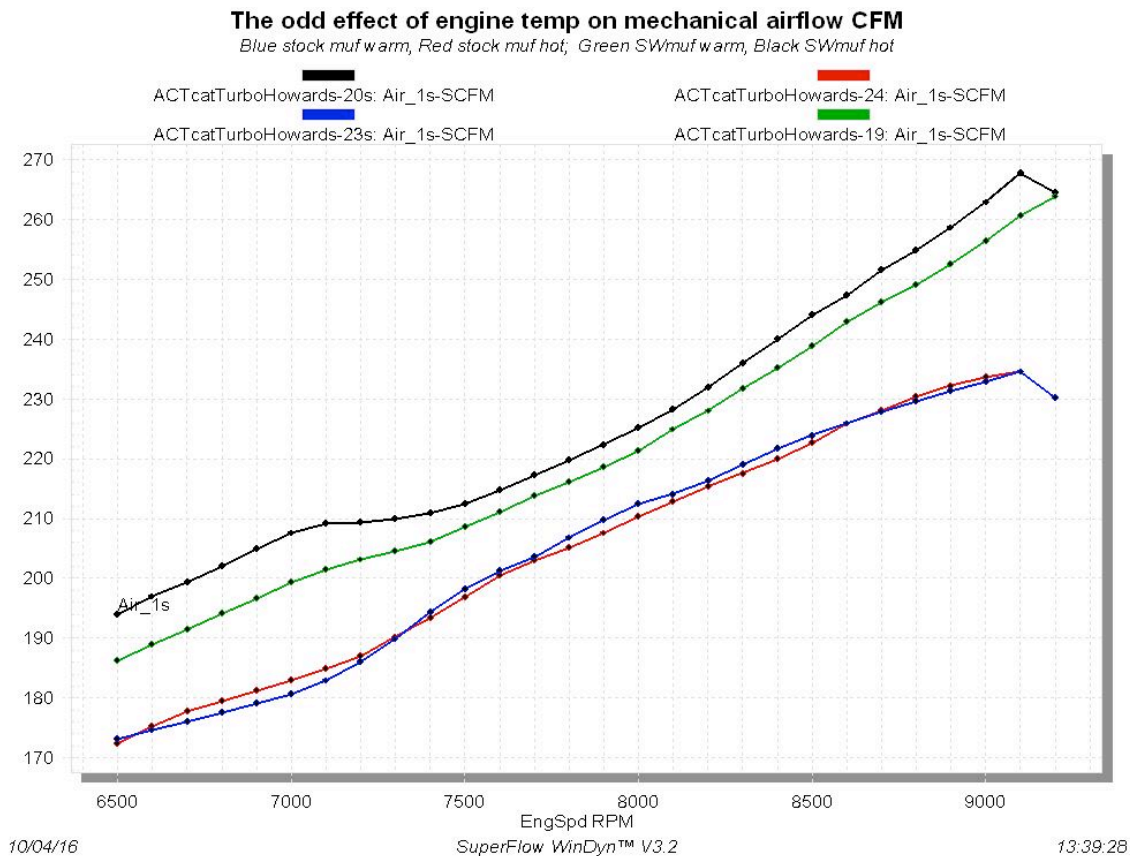
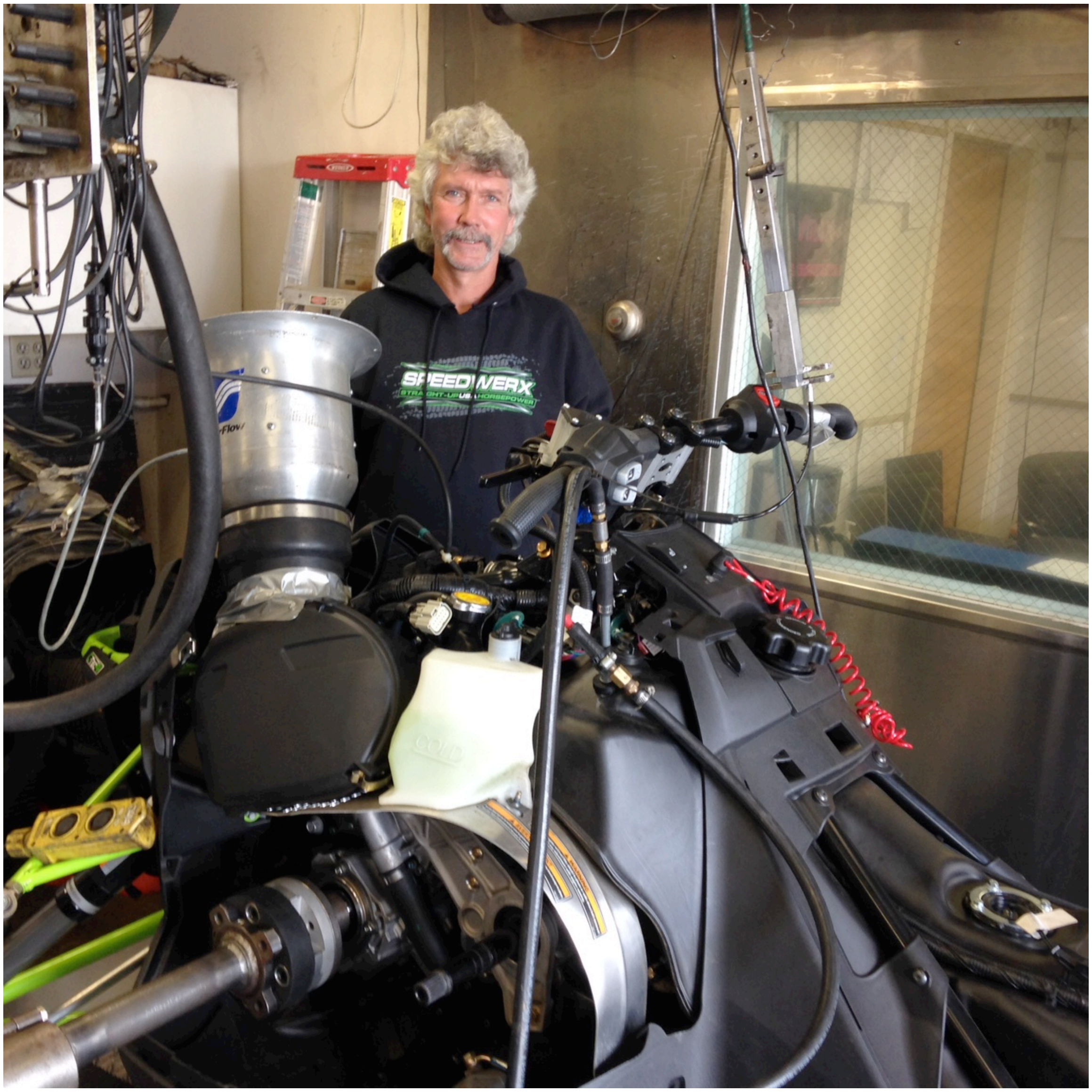


Note on the above graph on engine temp/ mechanical airflow CFM: With stock muffler, airflow CFM is nearly identical on both warm and hot dyno tests yet observing the HP graph we see HP reduced by four HP. That would indicate that ignition timing may be reduced at higher coolant temp—something that would likely affect the Speedwerx muffled tests as well.


SPEEDWERX