# SQUISH CLEARANCE AND ITS EFFECT ON ENGINE PERFORMANCE

Before absorbing this technical info, it's good to review Kevin Cameron's tech articles "Detonation" posted here on 1/31/14 and "Turbulence Needed" posted here on 3/4/15.

When I designed and built this SuperFlow engine dyno "In Chassis" testing facility in 1986 it was set up to accommodate snowmobiles, motorcycles, or any other vehicle small enough to fit on the diamondplate topped hydraulic scissors lift that had its output shaft (crank or transmission) on its left side. Then, there were no roller dynos for motorcycles--this was the only public place that I know of besides Jerry Branch's L.A. SuperFlow chain drive motorcycle dyno to test stuff with an automated fully instrumented dyno. So I was fortunate that smart people with racing motorcycles would come here from all over the country to dyno test. I pay attention, and listen well!

Early on, when Bob Blizniak's NYS grass drag champion Yamaha 440 SRX race engine made 100HP at the crankshaft, I was most fortunate to have Kevin Cameron (technical editor at Cycle World Magazine and motorcycle builder/ tuner for the likes of Kenny Roberts) come here as consulting engineer for then-rookie TX highschooler Colin Edwards' motorcycle roadrace team that was funded by actor Woody Harrelson. The tiny Yamaha twin cylinder two stroke TZ250 blew my mind with 90HP at the trans output shaft (@100HP at the crank after figuring gear drive friction losses)! The acronym "WTF?" had not yet been coined, but that's what I was feeling. This was not some violent 6 second drag engine, but one that could run for miles at WOT with 150 degreeF coolant temp on 108 octane fuel! That's when I realized that us snowmobile hotrodders were stuck in the Neanderthal Age. Help!

Fortunately, Kevin understood our plight, and was surely intrigued with a then-young guy learning everything he would know on a fully instrumented dyno, and agreed to help out as "Technical Editor" for DynoTech in the years that we tested things and mailed out printed issues to members (all scanned and posted at the bottom of this website). There are some 30 KC "The Cellar Dweller" articles on this website explaining things two-stroke that has helped many sled engine modifiers finally match (and sometimes exceed) the 180+psi BMEP that the two-stroke roadrace bikes made in the 1980's and beyond. Tim Bender and Sean Ray were able to eventually get their Hentges Racing 600 Polaris SnoX mods to 200psi BMEP (see the article posted here on 5/16/2012) before they were outlawed, and both credit what they had learned from KC both personally and from DTR articles for the great HP they were able to achieve.

But now even those 100HP TZ250s are seemingly obsolete--the latest iterations of 125cc roadrace two-strokes are said to make 65HP! So when Kevin Cameron talks about .027" squish clearance for our sled racing engines as possibly being optimal, we should listen!

Local lakeracer Pete Nixon had recently acquired an SSI arctic Cat 800/ 950 big bore with custom cast cylinders and billet head for his Crossfire. It came with moderate 14/1 uncorrected compression ratio and thick (.072") squish clearance. Rob Schooping of

HTG is still modding engines, and he tweaked the port timing/ shapes of this engine before Pete brought it to the dyno. He has a full SLP ceramic coated 800 exhaust.

We dyno tuned the engine with C12 race gas, making maximum HP at 13.3ish/1 A/F and created a timing curve that gave best midrange, peak and over rev HP with a Power Commander tuner.  Here's the optimal data after tuning to absolute max dragracing HP:

**14/1 compression ratio, .072" squish clearance**

| EngSpd | STPPwr | STPTrq | BSFA | FuelA | LamAF1 | LM1Air | ExhPrs | Exh_1 |
|---|---|---|---|---|---|---|---|---|
| RPM | CHp | Clb-ft | lb/hph | lbs/hr | Ratio | SCFM | psig | deg F |
| 7200 | 156.2 | 113.9 | 0.656 | 97.7 | 13.16 | 287 | 3.1 | 872 |
| 7250 | 156.9 | 113.7 | 0.655 | 98.0 | 13.11 | 287 | 3.2 | 877 |
| 7300 | 158.2 | 113.9 | 0.663 | 99.9 | 13.03 | 291 | 3.4 | 877 |
| 7350 | 159.8 | 114.2 | 0.662 | 100.7 | 13.00 | 293 | 3.4 | 872 |
| 7400 | 162.7 | 115.5 | 0.660 | 102.3 | 12.95 | 296 | 3.5 | 859 |
| 7450 | 164.3 | 115.8 | 0.654 | 102.3 | 12.94 | 296 | 3.5 | 864 |
| 7500 | 166.5 | 116.6 | 0.647 | 102.6 | 12.95 | 297 | 3.5 | 879 |
| 7550 | 169.0 | 117.6 | 0.641 | 103.1 | 12.97 | 300 | 3.6 | 899 |
| 7600 | 171.9 | 118.8 | 0.634 | 103.6 | 13.01 | 302 | 3.7 | 930 |
| 7650 | 174.0 | 119.5 | 0.627 | 103.7 | 13.01 | 303 | 3.8 | 959 |
| 7700 | 175.6 | 119.8 | 0.621 | 103.7 | 13.01 | 303 | 3.8 | 968 |
| 7750 | 177.7 | 120.4 | 0.613 | 103.6 | 13.03 | 303 | 3.9 | 987 |
| 7800 | 179.8 | 121.1 | 0.604 | 103.3 | 13.07 | 303 | 4.0 | 1006 |
| 7850 | 181.6 | 121.5 | 0.598 | 103.1 | 13.10 | 303 | 4.0 | 1014 |
| 7900 | 184.5 | 122.6 | 0.587 | 102.9 | 13.23 | 306 | 4.1 | 1045 |
| 7950 | 186.3 | 123.1 | 0.581 | 102.8 | 13.25 | 306 | 4.1 | 1054 |
| 8000 | 189.0 | 124.1 | 0.571 | 102.5 | 13.30 | 306 | 4.2 | 1068 |
| 8050 | 191.3 | 124.8 | 0.563 | 102.2 | 13.34 | 306 | 4.2 | 1071 |
| 8100 | 193.9 | 125.7 | 0.554 | 102.1 | 13.42 | 308 | 4.2 | 1073 |
| 8150 | 196.0 | 126.3 | 0.550 | 102.3 | 13.48 | 310 | 4.3 | 1080 |
| 8200 | 197.6 | 126.6 | 0.547 | 102.7 | 13.42 | 310 | 4.3 | 1097 |
| 8250 | 198.4 | 126.3 | 0.546 | 102.8 | 13.35 | 308 | 4.3 | 1111 |
| 8300 | 198.1 | 125.3 | 0.546 | 102.7 | 13.37 | 309 | 4.3 | 1116 |
| 8350 | 195.8 | 123.2 | 0.551 | 102.3 | 13.45 | 310 | 4.2 | 1113 |
| 8400 | 190.3 | 119.0 | 0.565 | 101.8 | 13.51 | 309 | 4.1 | 1118 |
| 8450 | 179.1 | 111.3 | 0.597 | 101.4 | 13.33 | 308 | 3.9 | 1087 |

Pete was pleased with his HP, but sort of bummed that he couldn't brag to his pals about having 200 HP. Rounding up is not an option, unacceptable at DTR. So I suggested that he follow KC's recommendation on squish clearance--have SSI's Erich Long make him a set of domes with identical 14/1 uncorrected compression ratio with larger bowls but .027" squish clearance. Because the SSI 950 Wiseco pistons sit down in the hole at TDC, all Erich could do is 14/1 with .039" squish clearance (no step at the edge). But the results would prove to be very worthwhile.

As Kevin Cameron suggests, tightening the squish results in normally wasted mixture being squirted back into the middle of the burning combustion chamber at TDC--not only providing more BTUs for making HP, but as KC says "stirring the pot once more" which increases flame speed. That requires reduced timing to create maximum combustion chamber pressure at @ 11 degrees ATC. In this case, Pete's engine required 3 degrees less timing to make max HP--meaning less time for heat to be absorbed into the domes instead of heating and expanding the air which pushes the piston down in the bores! And, that means less time for deto to occur. Win-Win!

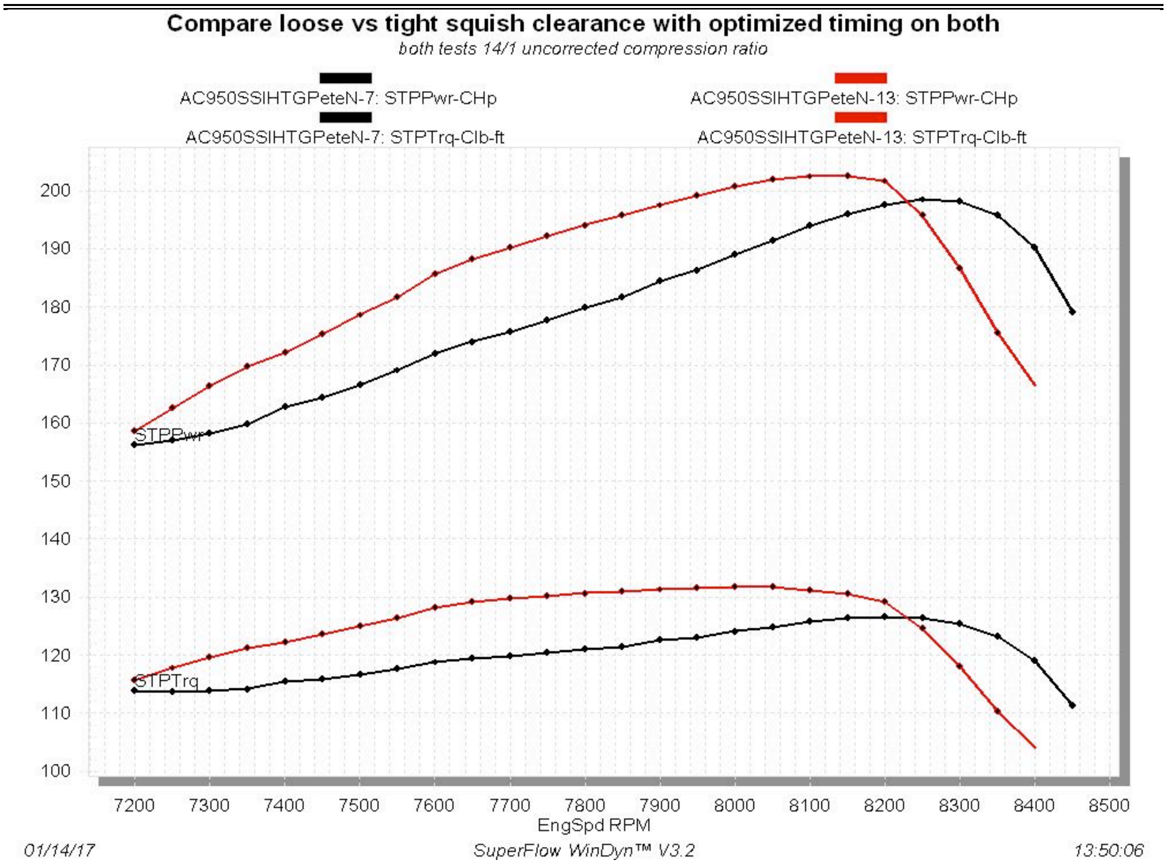
So what we see here is an interesting combination of lower pipe center section temperature (more air/fuel mixture being burned in the combustion chamber instead of out in the pipe), higher airflow CFM (which surely helps purge more deto-causing active radicals out of the combustion chambers), and reduced backpressure (which may reduce supercharging effect--there may be more HP available with tighter outlet pipe for dragracing, but no time for that today).

Note that the lower pipe temp was the result of more energy being used to push the pistons down their bores instead of burning out in the pipe creating high temps and backpressure. On this test, we even slowed the acceleration rate on the dyno from 250 RPM/sec to 200 RPM/sec to try to get the pipe as hot as it was with the fat squish, and *still* failed to match the high temp of the fat squish test. So it's probably a combo of the slower speed of sound *and* the higher operating compression ratio (more mixture squeezed out of the squish area into the bowls, and being burned at and after TDC) that has lowered peak HP RPM.

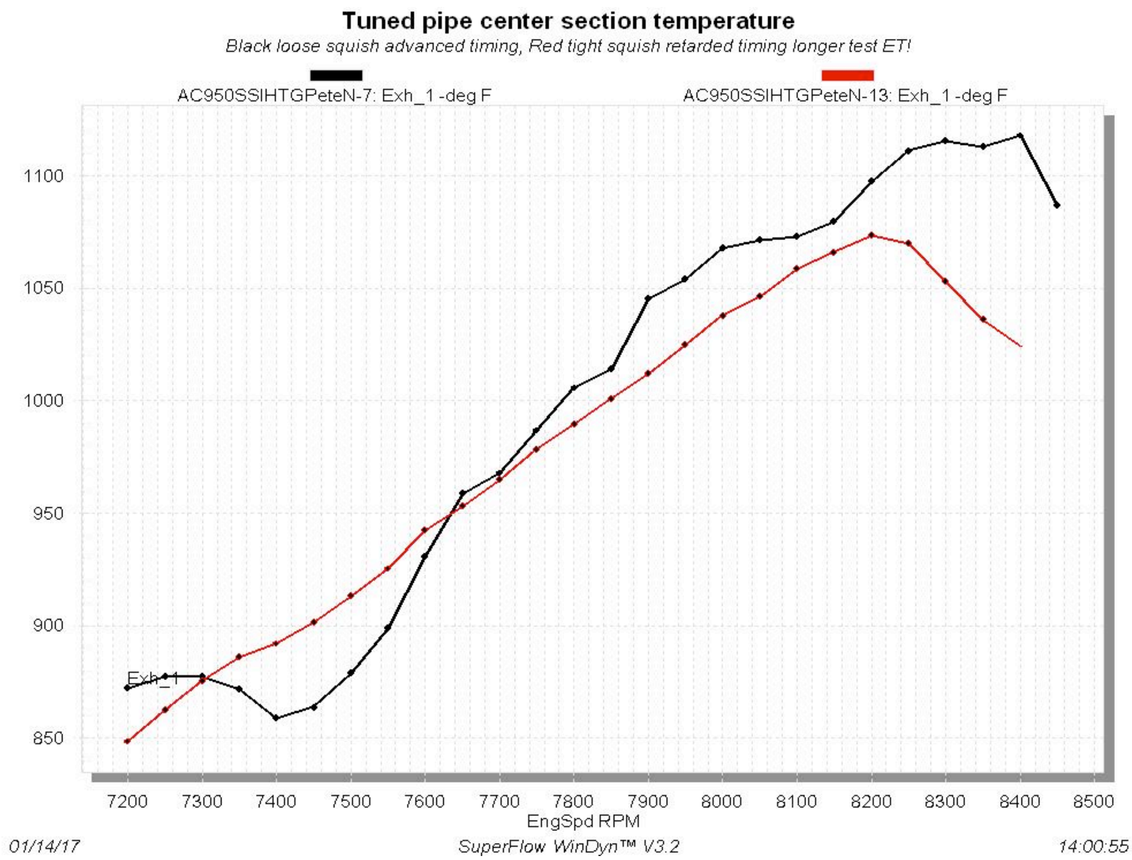
**14/1 compression ratio, .039" squish clearance**

| EngSpd<br>RPM | STPPwr<br>CHp | STPTrq<br>Clb-ft | BSFA<br>lb/hph | FuelA<br>lbs/hr | LamAF1<br>Ratio | LM1Air<br>SCFM | ExhPrs<br>psig | Exh_1<br>deg F |
|---|---|---|---|---|---|---|---|---|
| 7200 | 158.6 | 115.7 | 0.631 | 96.7 | 13.11 | 281 | 2.3 | 848 |
| 7250 | 162.6 | 117.8 | 0.632 | 99.3 | 13.10 | 289 | 2.4 | 863 |
| 7300 | 166.3 | 119.6 | 0.630 | 101.1 | 13.09 | 294 | 2.5 | 876 |
| 7350 | 169.7 | 121.3 | 0.624 | 102.1 | 13.07 | 297 | 2.8 | 886 |
| 7400 | 172.2 | 122.2 | 0.622 | 103.3 | 13.06 | 300 | 3.0 | 892 |
| 7450 | 175.3 | 123.6 | 0.625 | 105.6 | 13.03 | 306 | 3.2 | 902 |
| 7500 | 178.6 | 125.0 | 0.624 | 107.4 | 12.97 | 310 | 3.2 | 913 |
| 7550 | 181.7 | 126.4 | 0.618 | 108.1 | 12.94 | 312 | 3.3 | 925 |
| 7600 | 185.6 | 128.3 | 0.606 | 108.2 | 12.99 | 314 | 3.3 | 942 |
| 7650 | 188.2 | 129.2 | 0.597 | 108.1 | 13.05 | 315 | 3.4 | 953 |
| 7700 | 190.3 | 129.8 | 0.589 | 107.8 | 13.09 | 315 | 3.4 | 965 |
| 7750 | 192.2 | 130.3 | 0.583 | 107.7 | 13.12 | 315 | 3.4 | 978 |
| 7800 | 194.1 | 130.7 | 0.577 | 107.7 | 13.12 | 315 | 3.5 | 990 |
| 7850 | 195.7 | 131.0 | 0.571 | 107.5 | 13.11 | 315 | 3.5 | 1001 |
| 7900 | 197.4 | 131.3 | 0.565 | 107.2 | 13.11 | 314 | 3.5 | 1012 |
| 7950 | 199.2 | 131.6 | 0.559 | 107.0 | 13.14 | 314 | 3.6 | 1025 |
| 8000 | 200.7 | 131.8 | 0.555 | 106.9 | 13.15 | 314 | 3.7 | 1038 |
| 8050 | 201.9 | 131.7 | 0.553 | 107.2 | 13.15 | 315 | 3.7 | 1046 |
| 8100 | 202.4 | 131.3 | 0.554 | 107.6 | 13.12 | 316 | 3.8 | 1059 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 8150 | 202.6 | 130.5 | 0.555 | 108.0 | 13.09 | 316 | 3.8 | 1066 |
| 8200 | 201.6 | 129.1 | 0.560 | 108.4 | 13.08 | 317 | 3.8 | 1073 |
| 8250 | 195.7 | 124.6 | 0.578 | 108.5 | 13.10 | 311 | 3.8 | 1070 |
| 8300 | 186.6 | 118.1 | 0.607 | 108.5 | 13.12 | 309 | 3.8 | 1053 |
| 8350 | 175.5 | 110.4 | 0.644 | 108.3 | 13.37 | 324 | 3.8 | 1036 |
| 8400 | 166.5 | 104.1 | 0.673 | 107.2 | 13.37 | 321 | 3.7 | 1024 |




This torque and HP increase (note the 10 lb/ft and 15 hp increase at 7700 due in part to the cooler pipe temp!) was made possible by the "imperfect storm" of excessively safe squish clearance and wide-ish (according to KC) bands. But when I do the fuzzy math, the thin slice of compressed air/fuel mixture seems to be much less than 2% (the peak HP increase as a %) of the total cubic inches in the combustion chamber at TDC--meaning that it was the turbulence increase helping burn the mixture in the middle of the combustion chamber more efficiently, more than just the newly released energy from the previously hidden mixture in the squish area.




We had much higher average pipe center section temperature with .072" squish heads. This surely implies that the excessive air/fuel mixture that is squeezed into the oversize squish area at TDC winds up burning too late to make HP--instead burning on its way out the exhaust port (along with some of the less turbulent non-squish A/F mixture) on its way into the pipe creating heat and backpressure there. The dip in the temperature from 72-7600 is likely the heavily advanced midrange timing of the "drag box" ECU programming creating a few clicks of deto right there.  We had to remove that excessive timing after tightening the squish clearance, and there were zero clicks of deto.

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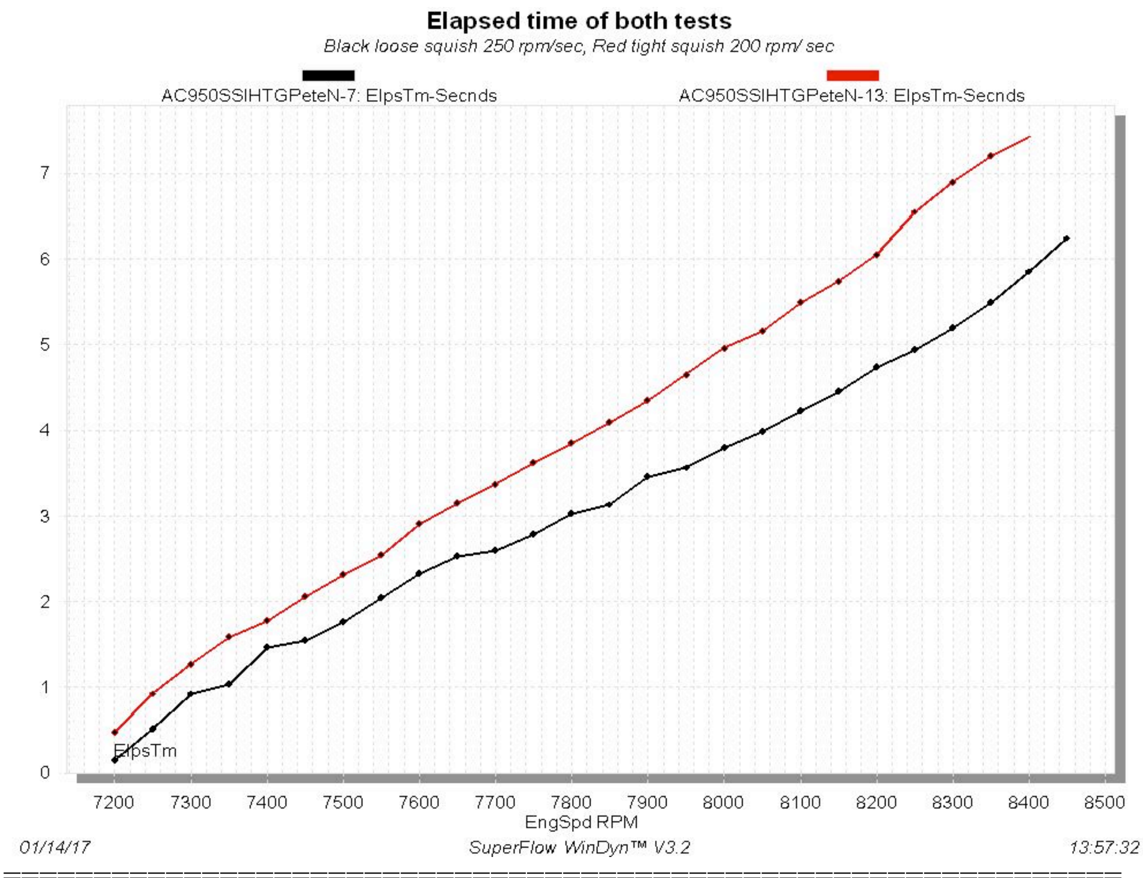

Elapsed time of both tests
Black loose squish 250 rpm/sec, Red tight squish 200 rpm/ sec
AC950SSIHTGPeteN-7: ElpsTm-Secnds
AC950SSIHTGPeteN-13: ElpsTm-Secnds
7
6
5
4
3
2
1
0
ElpsTm
7200
7300
7400
7500
7600
7700
7800
7900
8000
8100
8200
8300
8400
8500
EngSpd RPM
01/14/17
SuperFlow WinDyn™ V3.2
13:57:32

Now that he saw the great improvement with his 950 lakeracer, Pete is planning to try the same with his high power Cat 800 "improved stock" hill drag sled that currently has a squish clearance of .058". He'll try for the KC recommended .027". Because he has a cut stock Arctic Cat head with known great cooling properties ("shrink wrapped" low volume turbulent coolant vs. "bathtub" high volume stagnant coolant) we expect the tight squish clearance to be doable. More experimenting to come!