

GASOLINE/ ETHANOL TUNING

Stock sled racers should have every possible engine horsepower to compete most effectively. I often suggest to dyno tuners that when we create maximum possible HP at the crank taper, we have only optimized 1/3 of what makes snowmobiles fast--the other 2/3 are clutching and chassis tuning. But having that first 1/3 perfect is a good start!

This past winter we have been improving the HP of some dyno tuned stock snowmobile engines by adding ethanol to the fuel--up to 15% (since E15 can be considered "pump gas"). Ethanol is great stuff--high octane (@100), high latent heat of vaporization (greatly cools intake charge as it vaporizes which increases airflow and lowers peak combustion chamber temps which helps prevent deto), and its oxygen content is high (35%! which requires added fuel flow for optimal A/F ratio). But its downside for tuners is its slower burn speed compared to gasoline (@15% slower which means timing must be advanced to keep peak cylinder pressure from being created too far after TDC to make max torque at any given RPM). So tuning various mixtures of gasoline and ethanol is easiest with Dynojet Power Commanders that can tune both fuel and ignition timing. On this day we had Canadian Scott Williams' "stock" Arctic Cat 800 which, when tuned for max HP on E5 (typical of high test "up to 10%" ethanol pump gas), made a bit more than typical bone stock 800s tuned this way, but Scott assured me that his engine would "pass ISR tech" (whatever that means). But he was glad to have us share this A to B tuning/ test session.

I'm of the opinion that all "race boxes" (ECU's reprogrammed by Arctic Cat either direct or through companies like D&D and Speedwerx) are not necessarily created equally. Is it a "grassdrag" box? Or a "1000 foot" box? Icedrag box? Was it tuned for Joe Factory Sponsored Racer, or Average Joe? We always seem to be able to improve the tuning of "race boxes" by tweaking fuel and timing. Summer pump gas has a RVP of 5 psi, and winter pump gas has more volatile 10 psi (to enable engine starting at -30F), so they surely need different tuning for max HP. On this day we tweaked Scott's fuel and timing to optimal on the 5% ethanol 93 octane winter fuel. Then we added just enough E85 pump gas to bring his ethanol content to 15% and retuned by adding fuel and adding timing. The net increase in oxygen content when going from 5% to 15% ethanol is about 3.25%!

For field tuners trying adding ethanol to their fuel, the most practical means of experimenting is with a wideband A/F gauge. If your engine is happiest with, say, 13.3/1 then try to keep that same reading after adding ethanol. Even though purist engineers may prefer lambda tuning (where "1" = stoichiometric) this method is fine. Then add some timing--one or two degrees PCV tuning or offset flywheel keys, using your clutches as a dyno.

Why worry about a few extra HP? We need them all! Some years ago, my dyno addicted pal Eric Johncox came to DTR to "fine tune on this pail of Sunoco Supreme" his son Cody's already dyno tuned RLJ modded 64ish HP (Dynojet RWHP) Yamaha 450 flat track race bike on their way to the prestigious Springfield Mile. I teased him for spending

valuable dyno time for tweaking an extra .85 HP optimizing fuel flow on this pail of Supreme. But after Cody won the Springfield Mile in a crazy six inch photo finish I had to apologize for the teasing. Yes, we need them all! And, if a \$2.20 gallon of E85 can add some legal HP to stock snowmobile racers, why not?

Also, note that the LM1air (computed engine airflow based upon measured fuel flow and wideband A/F readings) are influenced by the added O2 in the E15 fuel. There surely should be some added mechanical airflow because of the denser intake charge temp, but the added O2 skews the LM1air readings a bit.

Here is our dyno test data going from 5 to 15% ethanol and optimizing dyno tuning for both. Anyone going from 0% to, say, 20% ethanol should have even greater increases in HP! Ethanol % testers are cheap \$10 test-tube-like instruments available from small engine dealers or Amazon.

"stock" Arctic Cat 800 twin, dyno tuned to max HP on 5% ethanol pump gas

| EngSpd RPM | STPPwr CHp | STPTrq Clb-ft | BSFA lb/hph | FuelA lbs/hr | LamAF1 Ratio | LM1Air SCFM | DenAlt Feet | STPCor Factor |
|---------------|---------------|------------------|----------------|-----------------|-----------------|----------------|----------------|------------------|
| 6500 | 106.9 | 86.7 | 0.59 | 59.9 | 16.42 | 221 | 1145 | 1.051 |
| 6550 | 108.4 | 87.1 | 0.59 | 60.6 | 16.36 | 222 | 1145 | 1.051 |
| 6600 | 109.9 | 87.6 | 0.59 | 61.3 | 16.30 | 224 | 1144 | 1.051 |
| 6650 | 111.5 | 88.1 | 0.59 | 62.3 | 16.24 | 227 | 1144 | 1.051 |
| 6700 | 113.2 | 88.7 | 0.59 | 63.2 | 16.14 | 229 | 1144 | 1.051 |
| 6750 | 115.2 | 89.6 | 0.59 | 64.3 | 16.03 | 231 | 1143 | 1.051 |
| 6800 | 117.5 | 90.7 | 0.59 | 65.4 | 15.91 | 233 | 1143 | 1.051 |
| 6850 | 119.6 | 91.7 | 0.59 | 66.6 | 15.81 | 236 | 1143 | 1.051 |
| 6900 | 121.8 | 92.7 | 0.59 | 67.9 | 15.68 | 239 | 1143 | 1.051 |
| 6950 | 124.2 | 93.9 | 0.59 | 69.3 | 15.54 | 242 | 1143 | 1.051 |
| 7000 | 126.6 | 95.0 | 0.59 | 70.5 | 15.42 | 244 | 1143 | 1.051 |
| 7050 | 129.0 | 96.1 | 0.59 | 71.7 | 15.30 | 246 | 1143 | 1.051 |
| 7100 | 131.5 | 97.3 | 0.59 | 73.0 | 15.18 | 248 | 1143 | 1.051 |
| 7150 | 133.9 | 98.3 | 0.59 | 74.1 | 15.05 | 250 | 1143 | 1.051 |
| 7200 | 136.3 | 99.5 | 0.58 | 75.1 | 14.93 | 252 | 1144 | 1.051 |
| 7250 | 138.8 | 100.5 | 0.58 | 76.0 | 14.83 | 253 | 1144 | 1.051 |
| 7300 | 141.2 | 101.6 | 0.58 | 76.7 | 14.76 | 254 | 1145 | 1.051 |
| 7350 | 143.5 | 102.6 | 0.57 | 77.3 | 14.70 | 255 | 1145 | 1.051 |
| 7400 | 145.8 | 103.5 | 0.57 | 77.8 | 14.65 | 256 | 1145 | 1.051 |
| 7450 | 148.1 | 104.4 | 0.56 | 78.3 | 14.61 | 257 | 1146 | 1.051 |
| 7500 | 150.5 | 105.4 | 0.55 | 78.8 | 14.57 | 258 | 1146 | 1.051 |
| 7550 | 152.7 | 106.2 | 0.55 | 79.3 | 14.53 | 258 | 1147 | 1.051 |
| 7600 | 154.9 | 107.0 | 0.55 | 79.8 | 14.47 | 259 | 1147 | 1.051 |
| 7650 | 157.2 | 107.9 | 0.54 | 80.3 | 14.40 | 260 | 1148 | 1.051 |
| 7700 | 159.5 | 108.8 | 0.54 | 80.9 | 14.32 | 260 | 1149 | 1.051 |
| 7750 | 161.7 | 109.6 | 0.53 | 81.4 | 14.25 | 260 | 1150 | 1.051 |
| 7800 | 163.8 | 110.3 | 0.53 | 81.8 | 14.18 | 260 | 1150 | 1.051 |
| 7850 | 165.7 | 110.8 | 0.53 | 82.3 | 14.11 | 261 | 1151 | 1.051 |
| 7900 | 167.3 | 111.3 | 0.52 | 82.7 | 14.04 | 261 | 1152 | 1.051 |

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|------|-------|-------|------|------|-------|-----|------|-------|
| 7950 | 168.8 | 111.5 | 0.52 | 83.2 | 13.97 | 261 | 1152 | 1.051 |
| 8000 | 169.9 | 111.5 | 0.52 | 83.7 | 13.91 | 261 | 1153 | 1.051 |
| 8050 | 170.6 | 111.3 | 0.52 | 84.3 | 13.83 | 262 | 1154 | 1.051 |
| 8100 | 171.0 | 110.9 | 0.53 | 85.0 | 13.74 | 262 | 1155 | 1.051 |
| 8150 | 171.0 | 110.2 | 0.53 | 85.8 | 13.64 | 263 | 1155 | 1.051 |
| 8200 | 170.6 | 109.3 | 0.54 | 86.5 | 13.54 | 263 | 1156 | 1.051 |
| 8250 | 169.7 | 108.0 | 0.54 | 87.2 | 13.43 | 263 | 1157 | 1.051 |
| 8300 | 168.1 | 106.4 | 0.55 | 87.7 | 13.33 | 262 | 1158 | 1.051 |
| 8350 | 165.6 | 104.1 | 0.56 | 88.1 | 13.22 | 261 | 1159 | 1.051 |
| 8400 | 162.9 | 101.7 | 0.58 | 88.4 | 13.12 | 260 | 1160 | 1.051 |
| 8450 | 160.1 | 99.3 | 0.59 | 88.8 | 13.01 | 259 | 1161 | 1.051 |

"stock" Arctic Cat 800, dyno tuned to max HP on 15% ethanol pump gas

| EngSpd | STPPwr | STPTRq | BSFA | FuelA | LamAF1 | LM1Air | DenAlt | STPCor |
|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| RPM | CHp | Clb-ft | lb/hph | lbs/hr | Ratio | SCFM | Feet | Factor |
| 6500 | 107.7 | 87.2 | 0.62 | 63.2 | 17.21 | 243 | 1057 | 1.050 |
| 6550 | 108.7 | 87.2 | 0.62 | 63.8 | 17.10 | 244 | 1058 | 1.050 |
| 6600 | 109.7 | 87.3 | 0.62 | 64.4 | 17.03 | 246 | 1058 | 1.050 |
| 6650 | 111.1 | 87.7 | 0.62 | 65.2 | 16.96 | 248 | 1059 | 1.050 |
| 6700 | 112.8 | 88.4 | 0.62 | 66.2 | 16.89 | 250 | 1059 | 1.050 |
| 6750 | 114.7 | 89.3 | 0.62 | 67.3 | 16.80 | 253 | 1059 | 1.050 |
| 6800 | 117.0 | 90.4 | 0.62 | 68.7 | 16.65 | 256 | 1059 | 1.050 |
| 6850 | 119.7 | 91.8 | 0.62 | 70.2 | 16.43 | 258 | 1059 | 1.050 |
| 6900 | 122.6 | 93.3 | 0.62 | 71.8 | 16.19 | 260 | 1060 | 1.050 |
| 6950 | 125.4 | 94.8 | 0.62 | 73.3 | 15.98 | 262 | 1060 | 1.050 |
| 7000 | 127.8 | 95.9 | 0.62 | 74.7 | 15.81 | 264 | 1061 | 1.050 |
| 7050 | 129.9 | 96.8 | 0.62 | 75.9 | 15.65 | 266 | 1061 | 1.050 |
| 7100 | 132.5 | 98.0 | 0.62 | 77.3 | 15.44 | 267 | 1061 | 1.050 |
| 7150 | 135.3 | 99.4 | 0.61 | 78.6 | 15.22 | 268 | 1061 | 1.050 |
| 7200 | 138.3 | 100.9 | 0.61 | 79.9 | 15.03 | 269 | 1063 | 1.050 |
| 7250 | 141.1 | 102.3 | 0.61 | 80.9 | 14.90 | 270 | 1063 | 1.050 |
| 7300 | 143.8 | 103.5 | 0.60 | 81.6 | 14.81 | 271 | 1063 | 1.050 |
| 7350 | 146.3 | 104.6 | 0.59 | 82.2 | 14.74 | 271 | 1063 | 1.050 |
| 7400 | 148.6 | 105.5 | 0.59 | 82.5 | 14.68 | 271 | 1064 | 1.050 |
| 7450 | 151.0 | 106.4 | 0.58 | 83.0 | 14.61 | 272 | 1064 | 1.050 |
| 7500 | 153.3 | 107.4 | 0.58 | 83.5 | 14.55 | 272 | 1065 | 1.050 |
| 7550 | 155.6 | 108.2 | 0.57 | 84.0 | 14.51 | 273 | 1066 | 1.050 |
| 7600 | 157.5 | 108.8 | 0.57 | 84.3 | 14.48 | 273 | 1066 | 1.050 |
| 7650 | 159.5 | 109.5 | 0.56 | 84.6 | 14.43 | 273 | 1066 | 1.050 |
| 7700 | 161.5 | 110.2 | 0.56 | 84.9 | 14.39 | 274 | 1065 | 1.050 |
| 7750 | 163.6 | 110.9 | 0.55 | 85.4 | 14.33 | 274 | 1065 | 1.050 |
| 7800 | 165.7 | 111.6 | 0.55 | 85.8 | 14.27 | 274 | 1065 | 1.050 |
| 7850 | 167.5 | 112.1 | 0.54 | 86.1 | 14.21 | 274 | 1065 | 1.050 |
| 7900 | 169.2 | 112.5 | 0.54 | 86.5 | 14.15 | 274 | 1064 | 1.050 |
| 7950 | 170.4 | 112.6 | 0.54 | 87.0 | 14.09 | 274 | 1065 | 1.050 |
| 8000 | 171.5 | 112.6 | 0.54 | 87.5 | 14.03 | 275 | 1065 | 1.050 |

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|------|-------|-------|------|------|-------|-----|------|-------|
| 8050 | 172.4 | 112.5 | 0.54 | 87.9 | 13.97 | 275 | 1066 | 1.050 |
| 8100 | 172.9 | 112.1 | 0.54 | 88.3 | 13.90 | 275 | 1066 | 1.050 |
| 8150 | 173.1 | 111.5 | 0.54 | 88.8 | 13.81 | 275 | 1067 | 1.050 |
| 8200 | 172.9 | 110.7 | 0.55 | 89.5 | 13.72 | 275 | 1067 | 1.050 |
| 8250 | 172.1 | 109.6 | 0.55 | 90.2 | 13.61 | 275 | 1069 | 1.050 |
| 8300 | 170.8 | 108.1 | 0.56 | 90.8 | 13.50 | 275 | 1070 | 1.050 |
| 8350 | 168.7 | 106.1 | 0.57 | 91.2 | 13.39 | 273 | 1070 | 1.050 |
| 8400 | 165.7 | 103.6 | 0.58 | 91.2 | 13.30 | 271 | 1071 | 1.050 |
| 8450 | 160.9 | 100.0 | 0.60 | 91.1 | 13.24 | 270 | 1071 | 1.050 |
| 8500 | 154.4 | 95.4 | 0.62 | 91.0 | 13.25 | 270 | 1071 | 1.050 |
| 8550 | 144.2 | 88.4 | 0.67 | 91.0 | 13.31 | 271 | 1072 | 1.050 |

Stock AC Crossfire 800 with Race ECU and Ypipe

Black tuned with 5% ethanol, Red tuned with 15% ethanol

