

HP cost to drive a Polaris 600 coolant pump to 9500 RPM

"Dancing with detonation"

Portmeister Justin Fuller of Full Power Performance began his two-stroke modifying career with Bender Racing as a teenager, first learning to modify engines under Tim Bender's wing. Later when Tim went to NASCAR Busch Grand National racing full time he sold the business to Terry and (then DynoTech editor) Debbie Paine. Terry bought and set up a SuperFlow engine dyno for optimizing their mod engines, and Justin had the only set of keys to their new dyno room. He obtained his Horsepower Masters' and PHD (Piled Higher and Deeper) degrees while grinding cylinders, cutting heads and pipes, and operating the Bender SuperFlow engine dyno for those years.

After Bender Racing ceased operation, Justin went on his own as FPP. Tim Bender's NASCAR career was cut short by a severe practice crash injury and he was replaced by then rookie Matt Kenseth.

Tim came back to snowmobile racing as Team Manager of Hentges Racing, Polaris SnowCross Racing. He hired former DTR/ Aerodyne tech and then Delphi combustion analyst Sean Ray to be his part time right hand crew chief. Because of Tim Bender's involvement, Hentges was tasked with providing optimal powerplants for all the factory sponsored snowcross teams. All of the engine development of first the 800 twins and later when ISR downsized to the 600 twins was done here at DTR by Tim and Sean and Justin/ FPP was their go-to port modifier. After the first 150 HP mod 600 twin engines from Polaris arrived, Tim and Sean spent many thousands of dyno tests here (mostly on one engine--made possible by optimimal torsional dyno driveshaft dampening media that makes testing at DTR easy on the engines) trying things including varying port timing, shapes and sizes by Justin that would ultimately bring that power level up to 170 HP and the BMEP to 200+ PSI (average combustion pressure on each power stroke from TDC to BDC) in the final year of the SnowCross 600 mods. (scroll down on this website to find a year-by-year synopsis of the evolution of the Polaris 600 mods from 150 to 170 HP).

So when the 600 mod engines were finally banned from SnoCross racing by ISR they became a reasonably priced commodity for dragracers and hill dragracers. Here is one purchased from Hentges by a midwestern racer who sent it to FPP for upgrading. The FPP upgrade included a shrinkwrapped billet head with near interference squish clearance and now fashionable minimal coolant volume that should increase the coolant velocity and turbulence that scours heat more effectively from the coolant side of the domes.

Early on as Tim, Sean and Justin increased BMEP of the 600 race engines to 200 PSI at low RPM, detonation was a problem even with 116 octane race gas. At some point, Polaris tried to help by increasing coolant pump speed by changing the gear ratio from crank to coolant pump shaft. So now we have 50 GPM coolant flow (free flow from engine to unpressurized cooling tower). But a more restrictive snowmobile heat exchanger system can create bubble-creating cavitation on the engine side of the coolant pump, sending insulating bubbles instead of liquid coolant to the topsides of the domes.

That insulation can create buildup of heat in the squish areas that can promote the creation of active radicals that can detonate, reduce HP and wreck engines.

More redundancy—when those active radicals auto-ignite and detonate (knock) during the pressure rise of normal combustion (first spark, then knock—“spark knock”), the flame speed goes from a controlled 40-50 ft/sec to the local speed of sound. This creates a shock wave that not only sounds like a tiny man with a hammer beating on parts inside the engine, but also scours away the insulating boundary layers of air that protect the aluminum (that melts at 1200F) parts from the 5000F fire of max power combustion chamber temperatures! We learned all of this from the many technical articles Kevin Cameron (TCD) penned for us in the scanned issues at the bottom of this website. Everyone should go there and absorb all of the TCD articles.

So here we are with this freshened up Hentges/ FPP 600 twin and greedy Justin Fuller wanted to see how much HP he might gain by using an electric pump vs. the mechanically driven pump. Why not just leave the coolant stagnant? Do we really need to circulate coolant in a 5 second dragrace? Yes the now-banned Polaris SnowCross mods needed circulation—making max HP by leaving the line at 50-60F coolant temp then never exceeding 80F in the longest races. Why no cold seizures? Cold seizures are caused not by some complicated thermodynamics, but by lean net A/F ratio in the combustion chambers caused by inadequate fuel vaporization. High RVP (as tested, not read off of the spec sheet)(see the Home Vapor Testing details on the Blog section here) fuel assures adequate vaporization without high engine temps needed for stale fuel. But can we "overcool" engines? Combustion pressure rise from heated expanding mixture creates torque and HP, and it's possible that overcooling can reduce the mixture expansion and pressure rise in the combustion chamber, reducing torque. So what I think we have is a balancing act—keeping domes just cool enough to prevent the formation of active radicals with 116 motor octane fuel, but not so cool that they absorb valuable combustion chamber heat and pressure rise that would otherwise be pushing the pistons down in their bores.

Friction horsepower increases exponentially, as the square of RPM. We can see that in the HP graph comparing having engine HP pump 50 gal/ min coolant flow to a battery powered pump at less than half the GPM.

But surely in this short acceleration test, 20 GPM is plenty to prevent deto and make maximum TQ and HP. So while a one HP advantage might seem insignificant to some, others who have lost some past race by inches would disagree.

Looking at the lower 20 GPM coolant flow of the FPP coolant pump we see what the engineers call "Delta T" or in us laymans' terms "change in temperature" is higher than we see in the higher 50 GPM stock coolant pump flow. But that heat rejection was adequate to allow deto-free operation at the HP level at 200+ PSI BMEP. So in this case, the FPP electric pump was adequate and preferable, but every engine with varying chamber volume / coolant flow / squish clearance / dome thickness etc might require

more or less coolant flow to optimize HP. If any of those are not optimal then fuel flow must be added to cool things off internally, preventing deto and reducing HP.

This is a great balancing act. The highly turbulent high velocity coolant flow of a stock coolant pump is often best, but those who desire extra HP by not pumping coolant flow must weigh the benefits of reduction of detonation by stock cooling vs. added deto with stagnant or reduced turbulence offered by zero flow or lower electric coolant pump flow. If inadequate coolant flow makes you run richer than optimal A/F mixtures to prevent deto, the HP you save by *not* mechanically pumping coolant might cause a net HP *loss*! Dyno testing while measuring coolant flow listening for deto like Justin Fuller did here can pay HP dividends.

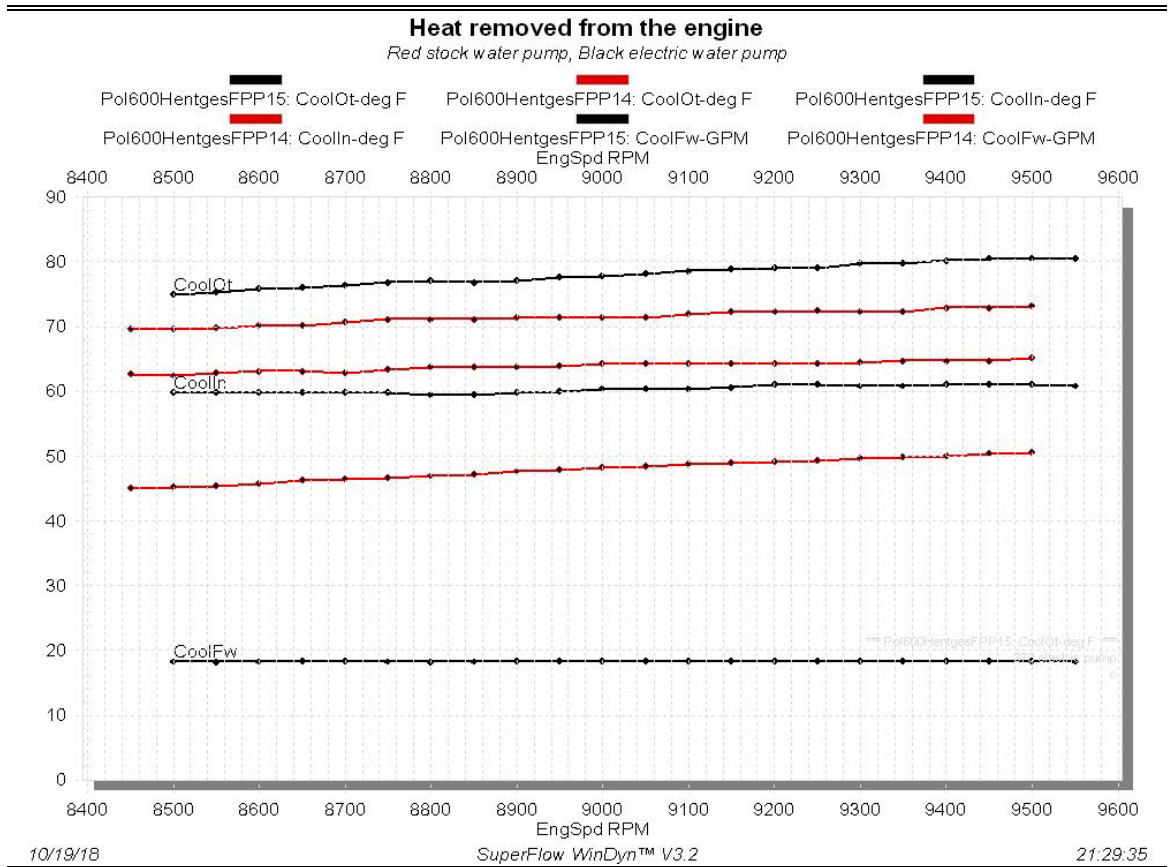
Hentges FPP 600 mod, stock coolant pump.

EngSpd RPM	STPPwr CHp	STPTrq Clb-ft	BSFB lb/hph	FuelB lbs/hr	BMEP psi	CoolFw GPM	CoolIn deg F	CoolOt deg F
8450	151.6	94.2	0.555	82.6	195.6	45.0	63	70
8500	152.2	94.0	0.556	83.0	195.2	45.2	62	70
8550	153.3	94.2	0.555	83.4	195.5	45.4	63	70
8600	154.6	94.4	0.553	83.8	196.0	45.7	63	70
8650	158.2	96.1	0.543	84.2	199.4	46.3	63	70
8700	160.5	96.9	0.539	84.7	201.1	46.4	63	71
8750	162.6	97.6	0.535	85.3	202.5	46.7	63	71
8800	164.2	98.0	0.533	85.8	203.4	46.9	64	71
8850	165.6	98.2	0.533	86.5	203.9	47.2	64	71
8900	166.7	98.4	0.533	87.1	204.2	47.6	64	71
8950	168.1	98.7	0.532	87.7	204.8	47.9	64	71
9000	169.2	98.8	0.533	88.4	205.0	48.2	64	71
9050	170.1	98.7	0.534	89.0	204.9	48.4	64	71
9100	170.5	98.4	0.535	89.5	204.3	48.8	64	72
9150	171.1	98.2	0.536	89.9	203.8	48.9	64	72
9200	171.2	97.7	0.537	90.1	202.9	49.2	64	72
9250	171.3	97.3	0.537	90.3	201.9	49.3	64	72
9300	170.7	96.4	0.539	90.2	200.1	49.6	64	72
9350	170.1	95.6	0.539	90.0	198.4	49.8	65	72
9400	168.8	94.3	0.542	89.7	195.8	50.1	65	73
9450	168.0	93.4	0.542	89.3	193.8	50.3	65	73
9500	166.6	92.1	0.545	88.9	191.2	50.5	65	73

Hentges FPP 600 mod, FPP electric coolant pump.

EngSpd RPM	STPPwr CHp	STPTrq Clb-ft	BSFB lb/hph	FuelB lbs/hr	BMEP psi	CoolFw GPM	CoolIn deg F	CoolOt deg F
8500	152.4	94.2	0.566	84.5	195.5	18.2	60	75
8550	153.5	94.3	0.563	84.7	195.8	18.2	60	75

8600	155.4	94.9	0.559	85.0	197.0	18.2	60	76
8650	158.5	96.2	0.550	85.4	199.7	18.3	60	76
8700	161.3	97.3	0.543	85.7	202.1	18.3	60	76
8750	163.4	98.1	0.538	86.1	203.6	18.2	60	77
8800	165.0	98.5	0.536	86.6	204.4	18.2	60	77
8850	166.2	98.6	0.536	87.2	204.7	18.2	60	77
8900	167.2	98.6	0.536	87.8	204.8	18.3	60	77
8950	168.5	98.9	0.536	88.4	205.2	18.2	60	78
9000	169.8	99.1	0.535	89.0	205.7	18.3	60	78
9050	171.0	99.2	0.535	89.6	205.9	18.3	60	78
9100	171.6	99.0	0.536	90.0	205.6	18.3	60	79
9150	172.1	98.8	0.536	90.3	205.1	18.3	61	79
9200	172.3	98.4	0.536	90.4	204.2	18.3	61	79
9250	172.5	97.9	0.535	90.4	203.2	18.3	61	79
9300	171.8	97.0	0.536	90.2	201.4	18.3	61	80
9350	171.1	96.1	0.536	89.7	199.5	18.3	61	80
9400	170.1	95.0	0.535	89.2	197.3	18.3	61	80
9450	169.4	94.2	0.533	88.4	195.4	18.3	61	80
9500	168.5	93.2	0.530	87.5	193.4	18.3	61	80
9550	166.8	91.7	0.530	86.6	190.4	18.2	61	80



Polaris 600 SnoX mod HP loss from mechanical coolant pump

Pol600HentgesFPP15, Pol600HentgesFPP14,

