Swamp's Diesel Performance
Competition Parts For Your Diesel
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Water Injection - Tests, Results, Conclusions . . .

Purpose Of Water Injection: A mist or spray of water introduced into the engine intake air stream has a powerful cooling effect, reducing the combustion temperatures and pressures. This reduces the likelihood of engine damage from excessively high temperatures and cylinder pressures under severe operating conditions.

Test Conditions: Ambient Air Temp 70* FEngine Water Temp 210*F by gauge. Engine has 195* thermostat. Water Temp held steady. Engine Oil Temp 215*F average 185*F min, 235*F max. Readings taken between 60 and 65 mph at 2300 to 2600 rpm. GCVW was about 22,500 lbs--10, 400 truck and 12,000+ trailer (33' long, 12' high)On dead flat road with no wind, boost was 6 psi, pre-turbine EGT was 750 and vehicle got 7.67 mpg. (9.47 mpg with a 15-20 mph tail wind)On flat road with 20-30 mph crosswinds, boost was 20 psi, pre-turbine EGT was 1250, and vehicle got 5.93 mpg. (I've got the aerodynamics of a large brick!)Information gathered during a trip from Brownsville, Texas, to Tucson, Arizona, and back, going US 83 through the West Texas hill country and Big Bend Mountains to I-10.

Engine Mods: 16:1 compression ratioK&N filter60 Hp SuperchipStage 1 Hypermax injectorsPropane injection NOT used during tests. No intercooler (I'm not advocating doing that, just reporting what I did.)1.00 A/R turbine housing3" downpipe into 3.5" straight pipe. Ceramic coated components from pistons; valves and heads clear through to turbine. Oversize 1.84" valves with ported heads.

Notes: Exhaust temperature readings were taken using 2 probes connected to a common gauge with a DPDT switchIt took 10-15 seconds to take both readings, which at 60 mph is about a 1/4 mile. However, due to constantly changing road and wind conditions, with the resultant constantly changing engine load, the pyro and boost gauges never held steady, but moved every few seconds, so each reading is really an "average". At idle with zero boost both probes read the same temperature (300*). The boost gauge reads 2-30 psi, the pyrometer reads 0-1500 degrees. The vertical distance between 2 points on the graphs is the temperature drop as the exhaust passes through the turbine.

With a 1.0 A/R turbine I have higher backpressure in the manifold, and thus higher pre-turbine temperatures, than with the stock 1.15 A/R unit, but there is also a greater drop in temperature as it goes through the turbine. The higher the boost, the greater the difference between pre- and post-turbine temperatures. If you have a post-turbo probe, at the higher boost levels your EGT's are significantly higher than you may realize. The post-turbine temperature is basically irrelevant to the engine, because only the exhaust pipes are exposed to it.

The pre-turbine temperatures are what the pistons and valves are exposed to. The "spikes" at 15 and 23 psi without water are from very long, steep hills where the engine was lugging, and should have been downshifted. On the last (hottest) 4 pre-turbo "wet" readings, the water tank may have run dry, but the engine was also lugging--speed had dropped to 55. If the tank wasn't dry, higher flow rates will be needed under these conditions.

Water Injection System: The tank is an old 10-gallon LP tank from a forklift, pressurized by the on-board air compressor. The compressor comes on at 80 psi and shuts off at 100, for an average pressure of 90. Water was originally routed to the engine with 1/4" poly tubing, but it kept melting even when wrapped with heat shield tape, so I went to 1/4" copper, with good results. I don't like copper in this application because of the possibility of vibration-induced metal fatigue. I recommend 1/4" reinforced robber fuel line instead.

A 12-volt solenoid valve in series controls the water flow with an adjustable pressure switch mounted on the MAP boost line, and a master switch in the cab. The power source in hot only when the key is on. The pressure switch was first set to close (on) at 12 psi and open (off) at 10 psi of boost; I changed it to 15 on and 13 off during the tests to conserve water. This does not materially affect the results. A LED light by the master switch indicates when the pressure switch closes and opens, to indicate when water is flowing. The water is injected into the "Y" pipe after the compressor where the compressed air splits to the cylinder heads.

Two nozzles are used, having a flat fan-shaped spray pattern. A screen-type filter is in-line just before the solenoid. I tried paper fuel filters, but they were not compatible with water. The nozzles are for agricultural sprayers, "TeeJet" part number PK-TP730154. Flow rates are .13 GPM at 30 PSI, .154 GPM @ 40 PSI, .17 GPM @ 50 PSI and .19 GPM @ 60 PSI. With the tank at 90 PSI, spraying into 20 PSI of manifold pressure, that gives 70 PSI equivalent at the nozzle which works out to .20 GPM times 2 nozzles for .40 GPM total flow.

A word of caution: With the system pressurized by an air compressor, if the solenoid valve should stick open, especially with the engine off, water will be pumped into the engine until the tank is dry, and next time it is started it will almost certainly hydro lock. For a permanent system, I will use an electric fuel pump instead, and have the pump in series with the pressure switch so it can only come on when there is boost. For now, I depressurize the system when not in use.

The Results: In short, IT WORKS! I'll let the numbers speak for themselves, and especially the graph. When the water turns on, there is a noticeable increase in engine power--I'd estimate as much as 10%--and there is a 15% increase in boost pressure. The power when the water comes on is like that from a mild shot of propane. The only downside was the large quantity of water required--it could empty the tank in as little as 1/2 hour where there were constant rolling hills. For extended use one would need a 40-60 gallon tank, which adds up to a lot of extra weight. Thus, an intercooler is the only practical solution for continuous engine cooling and the water should be reserved for the extreme WOT and high boost/extreme EGT situations. There are two reasons why I did not seem to get any results during all my previous experiments with water:

First, I was expecting to be able to see the EGT's start dropping as soon as the water came on, but that is not the case. Although the cooling effect is dramatic, the water needs to come on before the temperatures start to rise. That is, it will keep the EGT's from climbing, but it can't bring them down once they get up, although even higher flow rates might change that. Second, I wasn't using high enough flow rates; before, I was barely running 20-30 psi above manifold pressure. This time I was running 60-80 psi. (90-psi tank pressure spraying into 20 psi of boost pressure equals 70 psi of actual usable pressure to flow the water.)

Pre- and Post-turbo temperatures. "Dry" = without water injection, "Wet" = with water injection.

Boost Pressure	Pre-Turbo Temp "Dry"	Post-Turbo Temp "Dry"	Pre-Turbo Temp "Wet"	Post-Turbo Temp "Wet"
0	300	300		
4	500	400		
5	600	450		
5	675	500		
5	750	575		
6	700	525		
6	750	550		
7	750	550		
8	775	575		

8	850	600		
8	850	575		
9	800	600		
9	825	600		
9	825	600		
9	900	675		
9	900	650		
9	925	625		
9	950	650		
10	850	600		
10	925	650		
10	1000	700		
10	1050	700		
11	975	659		
11	1000	675		
11	1025	675		
12	1050	700		
12	1050	700		

12			825	575
13	1100	750		
13	1200	850		
13			875	575
13			900	600
14	1050	725		
14	1075	700		
14	1125	775		
14	1150	750		
14	1200	825		
14			950	625
14			950	600
15	1050	725		
15	1050	725		
15	1100	750		
15	1350	900		
15	1425	925		
15			1025	650

16	1125	750		
16	1125	700		
17	1200	750		
17	1300	875		
17			950	600
17			1100	650
18			1100	675
19			1150	700
20	1200	800		
20	1270	800		
20	1400	900		
20			1100	675
20			1100	675
20			1100	675
20			1175	700
21			1125	650
22			1200	700
23	1300	775		

23	1400	825		
23			1225	725
24	1250	825		
25	1400	900		
25	1400	875		
25	1400	900		
25			1300	750
25			1350	750
25			1400	825
27	1450	875		
27	1500	1000		
30			1425	800

The Graph: The two lines with the triangles represent the EGT's without water. The upper is pre-turbo temperature, the lower is post-turbo. The two lines with the squares are EGT's with water injection, the upper being pre-turbo and the lower post-turbo. The vertical distance between any two triangles or squares is the temperature drop as the exhaust passes through the turbocharger.

During testing four things were very noticeable: First, the EGT's were several hundred degrees cooler. Second, whenever the water came on, there was a 2-4 PSI (about 15%) increase in boost pressure. Third, there was a noticeable increase in engine power. Fourth, the sharp clatter in the engine sound smoothed out.

As the water enters the intake air stream at 15 psi of boost, the water is at a temperature of about 80* F and the air is at a temperature of about 250* F. (Compressing 80* air to 15 PSI increases its temperature by about 170*) Since water vaporizes at 212* F, it will absorb heat from the air (turning to steam) until the air temperature drops below 212*. The remainder of the water is atomized and remains suspended in the air stream, just as gasoline does when the air goes through a carburetor. During the combustion cycle, this atomized water absorbs more heat becoming completely vaporized.

The temperature drop through the turbine represents energy in the form of heat and pressure, which is extracted from the exhaust gasses and converted into mechanical, rotating energy. The increased temperature drop with the water injection means that the turbine is extracting more heat and pressure energy from the gasses making it spin faster, and this faster rotation is why the boost pressures increased. I believe that this increase in turbine speed is partly attributable to the mass of the water in the exhaust stream in that the increased mass applies more force to the turbine, and partly to the increased gas volume/pressure contributed by the steam.

The increase in engine power and reduction of "clatter" are related. The clatter is from the high peak pressures generated during the combustion cycle, and the water reduces these peak pressures. However, only the peak pressure is reduced. The BMEP (Brake Mean Effective Pressure), the pressure that is available to push the piston downward, actually increases, and this is the increase in engine power.