Water Methanol Injection on Diesel Engines for Combustion Cooling and Enhanced Engine Performance.

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Diesel Combustion -The diesel engine uses compression to ignite the air fuel charge that enters the cylinder. Diesel engines will typically be between a 16:1 to 25:1 compression ratio. For comparison, gasoline engines usually do not run higher than 11:1 compression without the aid of higher octane fuel to prevent preignition of the fuel charge. Preignition in a gasoline engine will result in piston damage or engine failure.

During the intake stroke on a diesel engine air is drawn, or forced with turbo charger, into the cylinder. When this air is compressed it is heated to around 1000F. Cylinder pressure can be around 600psi during compression.

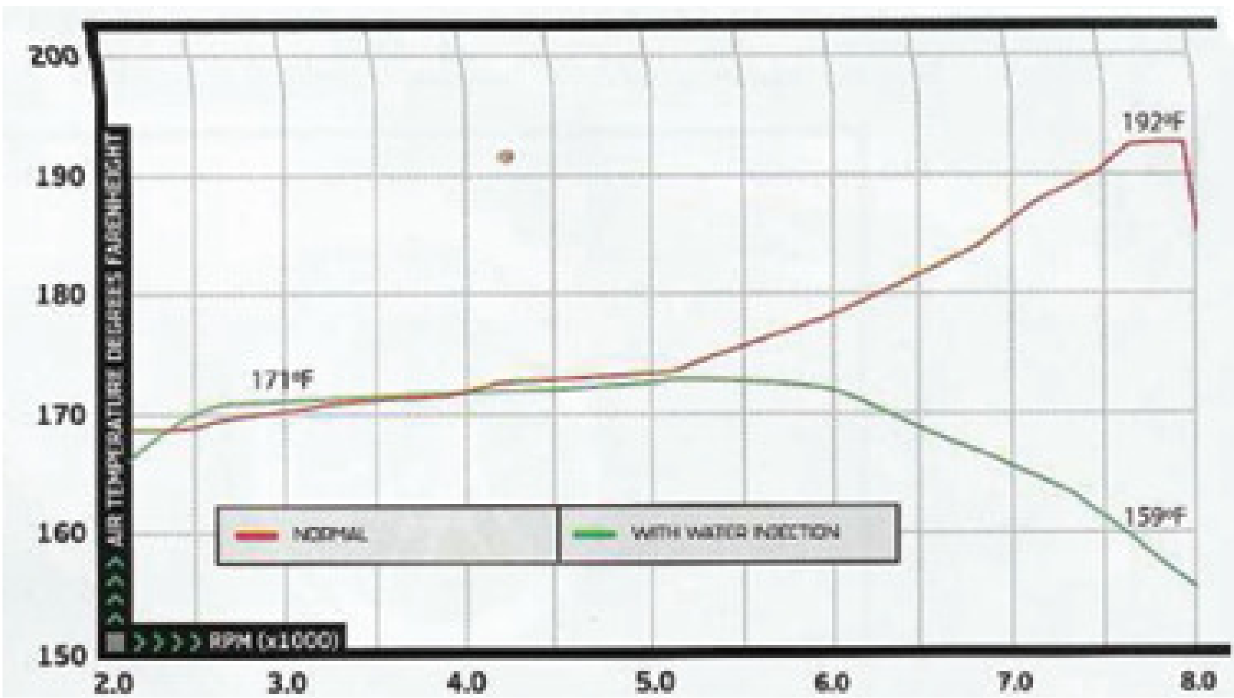
At or near TDC (Top Dead Center) fuel is injected into the cylinder. Due to the high temperature of the compressed air, the diesel fuel ignites. This produces a greater in cylinder pressure and forces the piston back down, hence doing useful work. Since diesel fuel ignites as it is sprayed in to the cylinder, there is little time for the fuel to mix with the intake air charge. The result is 15-30% of the fuel not being burned during combustion.

Diesel engines produce more horse power and torque simple by adding more fuel. Increased fueling allows more work to be done by the engine, but the side effect is that Exhaust Gas Temperatures (EGTs) increase almost proportional to the increased fueling. Temperatures that exceed 1300F can result in engine failure and or reduced engine life.

Water Methanol History - Water Injection was first successfully implemented in WWII on the P-47 “Thunderbolt”. The Turbo Charged Pratt & Whitney R-2800 engine normally produced 2000 HP, with water injection the engine could produce up to 3800 HP. With water injection, the P-47 had 20 minutes worth of high power output for combat situations. One initial problem was that at high altitudes the water would freeze. So to prevent freezing, methanol was finally added to the injection mixture. Later studies done by the Army Corp of Engineers actually determined that with a 50/50 mix of water-methanol even more power could be produced over water injection alone.

Water Injection on Diesels - LMS water injection systems spray a highly atomized mixture into the engines air intake path. The intake air density is increased from the added mass of finely atomized water particles. If the water particles are of small size (less then 40um) the increased surface area of the particles is sufficient enough to absorb heat out of the intake air. When the temperature of the intake air is lowered, the density of the air being drawn, or forced, into the engine cylinder is also increased.

The first benefit of water injection is intake air charge cooling. By cooling the intake air, more oxygen molecules enter the cylinder through a denser air charge. More oxygen can help to feed the combustion process resulting in a more complete fuel burn.

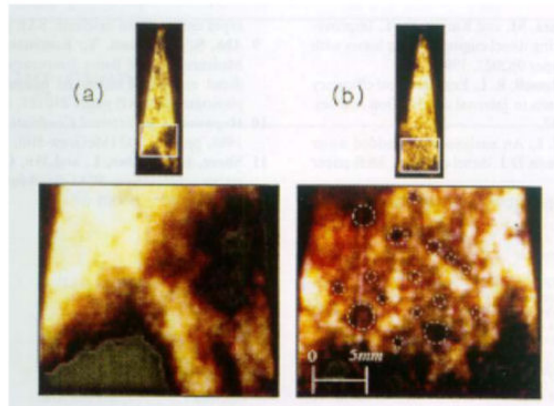


Water Injection Intake Air Charge Cooling on Turbo Gasoline Engine.

When the water particles enter the hot cylinder during intake, they absorb heat and convert to stream. The added mass to the combustion process helps to extend the downward force on the piston during the power stroke of the motor. The result is more torque produced by the motor similar to older steam engines. If too much water is injected, diesel combustion will be quenched as there will not be enough heat to sufficiently ignite the diesel fuel. The end result will be a loss of power. LMS water injection systems are designed to inject the correct amount of atomized fluid into the intake based on engine load to optimize the diesel combustion process.

Water Methanol Injection - Methanol is hygroscopic, meaning it absorbs water. During intake injection, the methanol molecules stay bonded with the water molecules and both enter the cylinder. The latent heat of evaporation of methanol is less then water. This basically means that less energy is required for methanol to go from liquid to gas state compared to water. During the compression stroke, as cylinder temperatures go up from compression, the methanol particles release from the water particles as they go from liquid to gas state. Once in gas state and at higher temperatures the methanol particles will ignite. This creates multiple combustion points distributed in the cylinder resulting in a more complete air to fuel burn.

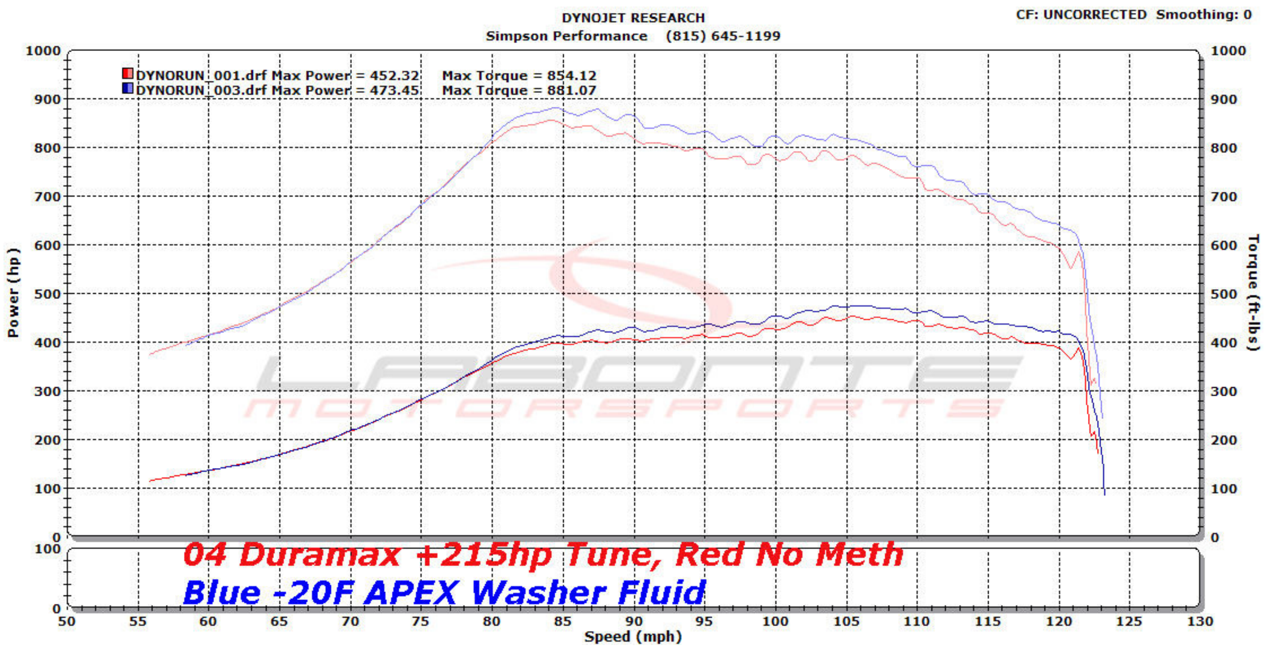
Once the diesel fuel is ignited, the remaining water particles begin to go from liquid to gas state very rapidly. The effect is multiple "micro explosions" as the water particles "pop". These micro explosions can range from barely identifiable to a few millimeters in size. The micro explosions are beneficial to the combustion process as they help "stir" the air/fuel charge mixture resulting in a more complete burn. In diesel combustion, as the water particles convert to steam they absorb heat. The net result is lower combustion temperatures. Exhaust Gas Temperatures can be reduced 250F-300F with water methanol injection which significantly lowers thermal stress on the engine components.



(a) normal diesel combustion (b) micro explosions 20% water

This is a similar effect that is attempted with HCCI (Homogeneous Charge Compression Ignition) for diesel engines. Homogeneous Charge simple refers to the complete combustion of the injected fuel. The current state of the art is implemented through multiple injection events during the combustion process. Small amounts of diesel fuel are injected in pre-ignition events. These pre-injections help to initiate combustion and create a "swirl" effect in the combustion chamber. Once the main injection event is initiated, the moving air mass generated from the pre-ignition "swirl" results in a more complete combustion of the diesel fuel. Post injection events are then initiated toward the end of the power stroke. These are required to re-establish the "swirl" effect that is diminishing as the cylinder volume is increased during the power stroke and helps burn off any left over fuel resulting in lower emissions. The limitation of HCCI is that fuel is still injected from a single injection point which presents challenges to distribute the fuel evenly with the intake air charge for complete combustion. Since water methanol injection occurs during the air intake stroke of the engine, the fluid particles are premixed with the air charge. The distributed particles can lead to a more efficient diesel burn than HCCI and at lower combustion temperatures. The result is a more complete combustion burn leading to higher torque, fuel economy, and lower emissions.

Methanol acts like a catalyst to help initiate diesel fuel burn in a cylinder cooled by water injection. Methanol also aids in a more complete diesel burn. Diesel engines initiate combustion through temperature and pressure. As the engines piston is forced down from combustion, the



volume of the cylinder increases and at some point combustion of the injected diesel fuel will stop. With the methanol distributed in the cylinder, a greater percentage of the injected diesel fuel will be used. Fuel economy can be realized from complete combustion through increased horse power and torque generated from the same volume of diesel fuel.

The above chart shows dyno test data that was conducted on a 2004 6.6L turbo diesel GM Duramax using the LMS DIS-100 injection system. The test fluid for injection was APEX -20F window washer fluid, which consists of about 25% methanol and 75% water by volume. Net result was an increase in rear wheel horsepower of 21 and 27 foot pounds of torque. Increases of up to 70 horse power can be obtained with a great mix ratio of methanol to water.

Conclusion:

Water-Methanol injection provides a cost effective means to lower diesel air intake temperatures by chemical intercooling the engine inlet air charge. Fuel economy can be achieved when the existing volume of fuel is fully combusted leading to increased horse power and torque.

Injecting water-methanol in a controlled quantity can result in a more complete air/fuel charge burn at lower temperatures that will extend the life of the motor and allow for larger loads to be pulled without overheating the engine.

Acknowledgments:

Wirbeleit F., Enderle CH., Lehner W., Raab A. Dinder K., “Stratified Diesel Fuel – Water – Diesel fuel Injection Combined with EGR – The Most Efficient Incylinder NOx and PM Reduction Technology”, SAE 972962, 1997

Bedford F., Rutland C., Dittrich P., Raab A., Wirbeleit F.
“Effects of Direct Water Injection on DI Diesel Engine Combustion”
SAE 2000-01-2938

Breda K., Pehan S., “Reduction of Diesel Engine Emissions by Water Injection”
SAE 2001-01-3259

McCutcheon K., “Frank Walker – What can I do about this problem?”
Internet Search

Vandeman J., Heinicke O., Effects of Water-Alcohol Injection and Maximum-Economy Spark Advance on Knock-Limited Performance and Fuel Economy of a Large Air-Cooled Cylinder, National Advisory Committee for Aeronautics, Memorandum Report E5H12

Park, J. W., et. All., Experimental study on the combustion characteristics of emulsified diesel in a rapid compression and expansion machine, Proc Instn Engrs Vol 214 Part D, ImechE 2000.