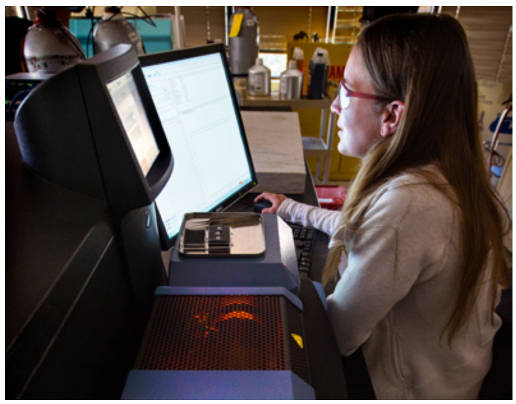
NREL
NATIONAL RENEWABLE ENERGY LABORATORY

New Analysis Methods Estimate a Critical Property of Ethanol Fuel Blends

Highlights in Research & Development

Methods developed at NREL disclose the impact of ethanol on gasoline blend heat of vaporization with potential for improved efficiency of spark-ignition engines.

More stringent standards for fuel economy, regulation of greenhouse gas emissions, and the mandated increase in the use of renewable fuel are driving research to improve the efficiency of spark ignition engines.



Senior scientist Gina Chupka uses a DSC/TGA instrument in NREL's analytical chemistry lab for fuels performance.
Photo courtesy of Dennis Schroeder, NREL 35762

When fuel properties such as octane number and evaporative cooling (heat of vaporization or HOV) are insufficient, they impact engine efficiency by forcing operation at less than optimal conditions because of engine "knock." Knock occurs when unburned fuel auto-ignites ahead of the spark-ignited flame front and, if severe, can cause extensive engine damage. Modern engines sense the onset of knock, and the engine control computer shifts the spark timing to non-knocking conditions but with a loss in engine efficiency.

HOV is a function of temperature and ethanol content for ethanol-hydrocarbon blends, and fuels with high HOV can have a cooling effect that potentially reduces engine knock. Ethanol has a very high HOV, nearly three times that of hydrocarbon gasoline components. Methods for accurately measuring the HOV of multicomponent fuel blends such as gasoline have not been well developed in the past.

NREL scientists have discovered methods to accurately measure the HOV in various ethanol blends containing from 10 volume percent (vol%) to 50 vol% ethanol. The researchers measured the performance properties and composition of the fuel blends, then performed detailed hydrocarbon analysis (DHA) that allowed for relatively straight-forward estimation of fuel composition and temperature effects on HOV for several different hydrocarbon blendstocks. HOV was also measured for different hydrocarbon blendstocks using a differential scanning calorimetry/thermogravimetric analysis (DSC/TGA) method.

To validate the accuracy of the DSC/TGA method, several pure components with known HOV values were measured. The method was in excellent agreement with values reported in literature as well as with those estimated using the DHA method. One striking feature of the results was that at temperatures up to 150°C, all the hydrocarbon blendstocks tested had nearly the same HOV and responded the same for blending of ethanol. Because of this, the theoretical temperature change for evaporation of fuel is, to a good approximation, a function of initial air temperature and ethanol content only, independent of the hydrocarbon blendstocks tested. If additional research shows that this result is general for all gasoline blendstocks, HOV could easily and accurately be estimated from an empirical correlation.

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Reference: Chupka, G., Christensen, E., Fouts, L., Alleman, T., Ratcliff, M., and McCormick, R. (2015). "Heat of Vaporization Measurements for Ethanol Blends Up To 50 Volume Percent in Several Hydrocarbon Blendstocks and Implications for Knock in SI Engines." *SAE Int. J. Fuels Lubr*. 8(2), 2015, doi:10.4271/2015-01-0763.

Key Research Results

Achievement

To date there have been no adequate methods for measuring the heat of vaporization of complex mixtures. This research developed two separate methods for measuring this key property of ethanol and gasoline blends, including the ability to estimate heat of vaporization at multiple temperatures.

Key Result

Methods for determining heat of vaporization of gasoline-ethanol blends by calculation from a compositional analysis and by direct calorimetric measurement were developed. Direct measurement produced values for pure compounds in good agreement with literature. A range of hydrocarbon gasolines were shown to have heat of vaporization of 325 kJ/kg to 375 kJ/kg. The effect of adding ethanol at 10 vol% to 50 vol% was significantly larger than the variation between hydrocarbon gasolines (E50 blends at 650 kJ/kg to 700 kJ/kg).

Potential Impact

The development of these new and accurate methods allows researchers to begin to both quantify the effect of fuel evaporative cooling on knock resistance, and exploit this effect for combustion of hydrocarbon-ethanol fuel blends in high-efficiency SI engines.

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

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