Key Messages from AMF Research

Annex 35-2 **May 2014**

Particulate Measurements: Ethanol and Iso-Butanol in Direct Injection Spark Ignited Engines

Debbie Rosenblatt and Christine Morgan (Canada), Steve McConnell (United States), and Jukka Nuottimäki (Finland)

Major Conclusion

Gasoline direct fuel injection (GDI) technology provides an alternative means to power gasoline vehicles and improve fuel economy, but has been linked to increased emissions of particulate matter. **The results of this research indicate the use of E85 as a transportation fuel is effective in mitigating PM increases from GDI vehicles.**

Background

Light-duty vehicles are a significant contributor to global greenhouse gas emissions (GHGs). Gasoline Direct Injection (GDI) engines offer fuel economy benefits and have begun to enter the global vehicle fleet mix as auto manufacturers search for ways to meet increasingly stringent light duty vehicle emissions regulations. With a GDI fuel system, the highly pressurized fuel is injected directly into the cylinder in a manner similar to a diesel engine..

However, **GDI engines can, under some conditions, produce high emissions of particles compated with conventional gasoline engines. The research within IEA AMF Annex 35-2 confirmed that the use of high concentration ethanol fuel (E85) reduces the particulate emissions of highly efficient GDI engines, thus enables lower GHG emissions without risking human health.**

Research Protocol

Canada was the Operating Agent for this international collaboration with Finland and the United States. Research was conducted over the period of November 2010 to May 2014 under the following test programs:

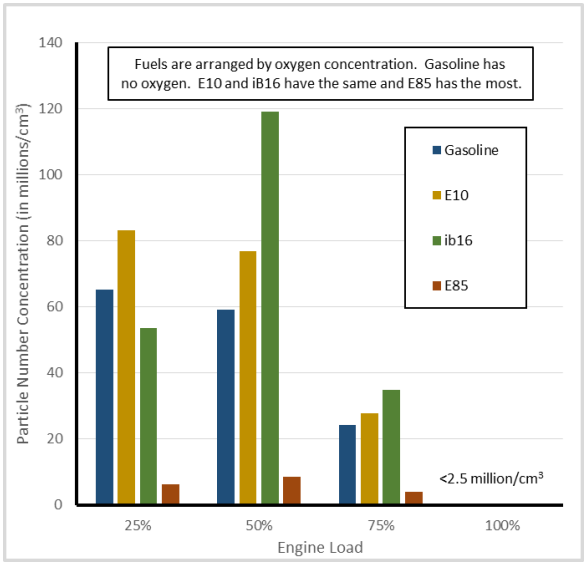
Canada – Performed chassis dynamometer emissions testing of a flex-fuel GDI vehicle and a standard GDI vehicle over a variety of fuel, drive cycle and temperature configurations. Real-time continuous monitoring using an Engine Exhaust Particle Sizer (EEPS) determined particle size and number emission rates. A Scanning Mobility Particle Sizer (SMPS) was used to access particle size and number emission rates from a GDI engine tested on an engine dynamometer. Primary particle morphology was investigated with a Transmission Electron Microscope (TEM).

United States – Used engine dynamometer testing to study particulate emissions from a General Motors GDI engine operating on alcohol blended fuels at different load levels. Particle size and number were determined with a SMPS and soot morphology was analyzed by TEM.

Finland – Conducted chassis dynamometer emissions testing on a turbocharged, direct injection, spark ignited engine run on E85 fuel using the New European Driving Cycle (NEDC). Particle size distributions were assessed by an Electrical Low Pressure Impactor (ELPI).

Key Findings

GDI technology provides an alternative means to power gasoline vehicles and improve fuel economy, but has been linked to increased emissions of particulate matter. **The results of this research indicate the use of E85 as a transportation fuel is a means to mitigate PM increases from GDI vehicles**. Key findings from the project can be summarized as follows:



- The use of **low- to mid- level alcohol blends (E10, E15, E20, iB16) with GDI engines/vehicles gave mixed results**; with some studies noting decreases in particles and others showing increases. In contrast to the low level ethanol blends the **E85 studies did yield consistent results indicating the potential to mitigate particulate emissions from GDI engines**.
- **E85 can reduce particle emissions from GDI engines under varying operating conditions and ambient temperatures**, as shown in the graph.
- **number of particles was roughly an order of magnitude lower with E85 as compared to E10** and resulted in reductions in the range of 70 -90%.
- Along with a reduction in particle number, the shape of the particle number distribution curve was also impacted with the **distribution peak occurring at a smaller particle size with E85 compared to E10 and E0**, still reducing particle numbers for all size classes.