

# **Propane Engine Fuel Study**

# Advancing knowledge in propane engine and emissions performance to meet regulatory requirements

ropane fuels more than 670,000 forklifts in the United States today. For many years, propane (also called liquid petroleum gas, or LPG) has been the fuel of choice for engine-driven forklifts because it supports durable engine fuel systems capable of widely varying engine speeds, with lower carbon monoxide emissions and engine maintenance costs than gasoline and diesel systems.

To demonstrate the propane industry's commitment to the forklift market and to continue industry efforts that ensure propane remains a clean and cost-effective fuel for forklifts, the Propane Education & Research Council (PERC) conducted its largest single research program to date, Investigation of Fuel System Technologies and Fuel Composition Effects on the Ability of Propane Forklifts to Meet 2007 EPA Emission Standards (Docket 10951).

This research program ensures that propane will be able to meet 2007 U.S. Environmental Protection Agency (EPA) regulations, which require transient cycle testing for large spark-ignition (LSI) non-road engine certification, and compliance with significantly lower emissions limits (see sidebar). In addition, the program provides reassurance to engine and forklift manufacturers that existing engine technologies can accommodate fuel contamination and variations in fuel composition.

# **EPA 2007 Emissions Challenge**

The new EPA 2007 standards are much more difficult to meet for several reasons:

- Transient testing (which uses variable speeds and loads) causes deviations in engine air/fuel ratios, which can increase emissions and degrade catalyst performance.
- Reducing CO emissions by 90% demands precise control of the fuel system.
- Increasing useful engine life by 40% creates greater concern about any causes of catalyst deterioration over the engine life (such as catalyst sulfur poisoning).

"The project shows that today's propane engines can meet tomorrow's EPA standards."

—Tucker Perkins, Chairman, PERC Engine Fuel Advisory Committee

# **Project Description**

Led by the Southwest Research Institute (SwRI), the research in **Docket 10951** pursued the following objectives:

- Evaluate the ability of closed-loop carburetion fuel injection technologies to meet EPA 2007 LSI engine standards.
- Explore the effects of LPG fuel quality variation on emissions deterioration to establish the fuel composition needed for adequate engine and emissions performance in forklift truck applications over the EPA 5,000-hour requirement.
- Determine the effect of LPG sulfur levels on forklift catalyst performance.
- Examine the effectiveness of fuel additives on fuel system durability and emissions deterioration.
- Characterize LPG fuels, residues, and deposits.





## Studying Effects of Fuel Impurities

LPG may contain heavy ends, which are non-volatile liquids or solids left in tanks or piping systems after propane is vaporized. Although heavy end contamination creates fuel system deposits that can affect drivability, performance, and emissions, this study found that these deposits did not significantly affect emissions in durability tests.

Despite these positive results, the propane industry remains committed to minimizing contamination and improving overall fuel quality. This project is one of several Council fuel quality initiatives dedicated to alleviating fuel quality concerns.



Heavy end intake valve deposits

# **Project Implementation**

The project was overseen by a steering committee including representatives from PERC, SwRI, propane producers and distributors, and forklift manufacturers. The test plan included the following:

- Fuel system investigation—transient cycle and steady-state testing of five fuel systems using three different forklift catalysts.
- Fuel quality effect testing—durability testing with six different fuel blends and two different additives; and 500-hour engine testing with 160 ppm sulfur fuel.
- Fuel and deposit analysis—collection of fuel samples from on-road vehicle and forklift fueling stations, and fuel deposit samples from fuel regulators, filters, vaporizers, and storage systems.

### **Project Completion: Key Conclusions**

#### **Fuel system investigation**

 Forklift engines with off-the-shelf electronic engine controls and three-way catalysts were able to meet 2007 EPA standards.

#### Fuel quality effect testing

- Based on 1,000-hour tests, emissions durability should be sufficient to meet a 5,000-hour useful life requirement.
- Propylene levels up to 30% had negligible impact on emissions performance of forklift engines with closed-loop feedback fuel controls and three-way catalysts.
- Current vaporizers and mixers can tolerate considerable heavy end deposition without emissions degradation.
- Occasional high sulfur levels did not impact long term catalyst emissions performance, which recovered after low sulfur fuel was reintroduced.

#### Fuel and deposit analysis

- Compounds over carbon number 20 (light oils and heavier) predominated vaporizer and mixer deposits.
- Phthalates (plasticizers extracted from hoses and seals), while present in all samples, constituted less than 1% of most deposits.
- The effectiveness of additives varied.

# SwRI Recommended Next Steps

Additional research should be performed to gain more insight about fuel quality and deposits, including:

- The sources of heavy ends.
- Deposit formation mechanisms.
- Deposit mitigation methods.
- Injector deposit formation rates and control measures.
- Intake port and intake valve deposits with additized LPG.
- Analytical methods for predicting LPG motor fuel deposit-forming potential.

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