Fuel Development & Testing LESSONS LEARNED 2014 through 2022

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Executive Summary

The objective of this document is to share the valuable lessons related to the collaborative work done by industry and the FAA through the Piston Aircraft Fuels Initiative (PAFI) and other important information in order to facilitate the development and approval of unleaded aviation gasoline(s) through a Fleet Authorization process or a Supplemental Type Certification process.

These lessons and best practices describe findings from fuel, engine and aircraft testing, observations, considerations as well as process related findings from the investigations. The photographs within are some of the more striking observations made during the course of testing different fuel formulations.

The considerations and recommendations provided are based on the observations and findings from previous testing and are not intended to reflect a singular path towards successful unleaded fuel development.

LESSONS LEARNED

from PAFI testing

LESSONS LEARNED

LL1

Materials compatibility, engine durability, and comingling with 100LL were shown to be the critical criteria overshadowing detonation as the key differentiator for acceptability of PAFI fuels. Effect of fuel characteristics on carburetor mixture cylinder to cylinder distribution was shown to be another area which can become a differentiator for acceptance of a new unleaded fuel.

LL2

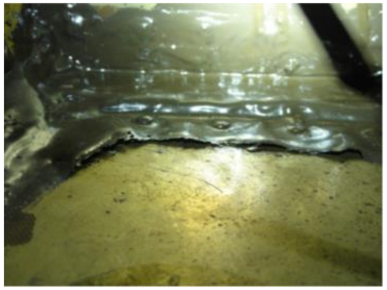
The test protocol work product of the Material Test Advisory Committee currently represents the industry's best practice for materials compatibility testing of a new fuel.

LL3 Materials Compatibility Observations: Fuel Bladder Wrinkling / Delamination

Fuel constituents such as aromatics may have solvent-like properties that are not compatible with existing fuel system materials.

LL4 Materials Compatibility: Polysulfide Tank Sealants

The impact of the fuel on the aircraft materials must be clearly understood and addressed. Fuel should not result in material functional degradation.



LL5

Materials Compatibility Observations Paint / Primer Staining / Removal

Fuel formulations may contain constituents which are not compatible with aircraft structure, paint, rubber, and other materials of non-fuel system aircraft components that may come into contact with fuel on a regular basis.

Engine Deposits

LL6 Successful completion of a durability test and materials compatibility testing were identified by PAFI as being critical risk mitigation criteria leading to release for flight test.

LL7 Effect of fuel formulation on combustion chamber and crankcase deposits is a consideration as it directly impacts engine wear.

See Appendix page 27 for more information.

LL8 Fuels with final boiling points higher than the ASTM D910 specification tended to have engine deposit issues which directly affect engine efficiency and wear.

Detonation performance

LL9

Detonation performance: Oxygenating compounds can result in leaner in-cylinder combustion conditions whose impacts may include higher operating temperatures and reduced detonation margins under full rich conditions.

LL10

Comparative detonation testing was demonstrated to be the preferred test method for validating acceptable detonation characteristics of a new unleaded fuel intended as a replacement for 100LL.

FUEL PROPERTIES THAT DIFFER SIGNIFICANTLY FROM ASTM D910

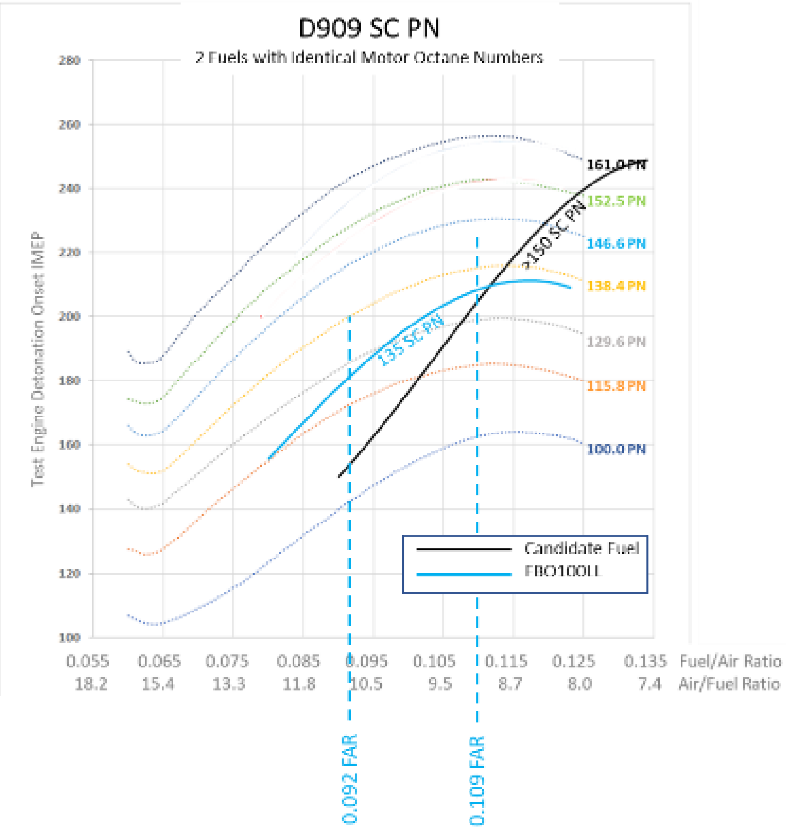
LL11 Unleaded fuels with properties and characteristics significantly different from those provided by ASTM D910 100LL leaded fuel have been shown to increase the scope of engine and aircraft testing. Each property that is different from ASTM D910 100LL will likely require unique tests to evaluate the impacts of those differences.

Such fuels have been shown to have greater impact on extent of changes to engine and aircraft that may be required to accommodate use of the fuel. This poses the potential for significant risks and challenges for implementation without changes to the existing fleet.

D909 SUPERCHARGE PERFORMANCE NUMBER & SENSITIVITY

LL12 A high ASTM D909 Supercharge Performance number result does not guarantee good supercharge performance in an engine at actual operating conditions. Raw data from D909 testing provides valuable insight into the fuel sensitivity.

- The graph on the right shows FBO100LL to be slightly more sensitive than the reference fuels, whereas the Candidate Unleaded Fuel has significantly higher sensitivity.
- Sensitivity can be affected by aromatic and oxygenate content
- D909 test may not be the ideal tool to effectively compare 100LL with unleaded fuels with different compositions due to the differences in performance curves.



Fuel Mixture Distribution

LL13

- Effect of fuel characteristics on carburetor mixture distribution (cylinder to cylinder Fuel/Air ratio) was shown to be an area which can become a differentiator for acceptance of a new fuel. This evaluation of fuel effect should be conducted on an engine model determined to be sensitive to fuel effects on mixture distribution, such as the Continental Model O-470-U engine.
- During Continental O-470-U mixture sweep testing, the fuel distribution characteristics based upon both EGT (Exhaust Gas Temperature) and AFR (Air/Fuel Ratio) sensor data were determined. Some fuel formulations tended to have higher levels of fuel mixture maldistribution that correlated with spark plug fouling. This excessive plug fouling correlated with cylinder misfire events. This high level of cylinder to cylinder mixture variability and excessive spark plug fouling (likely due to rich conditions caused by increased fuel density) is unacceptable.