PAFI
Piston Aviation Fuels Initiative
Future Unleaded Aviation Gasoline

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Presenters

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Why Are We Discussing This?  
Tetra-Ethyl Lead

Challenges to long-term leaded fuel availability

• Petitions and suits by environmental organizations
  • EPA is being sued to determine if lead from GA A/C endanger public health

• Pending EPA regulation
  – Reduced ambient air quality standards
  – Endangerment finding – lead from GA A/C

• Market forces
  – Single source of Tetra-ethyl lead
  – Lead phased out of most every other product
  – Local areas are putting pressure on airports to eliminate lead
Environmental Considerations

Clean Air Act (CAA)

- 42 U.S. Code § 7571 gives the EPA authority to establish emissions standards on any pollution source determined to endanger public health.
- The EPA must consult with the FAA in establishing these standards.
  - Standards should take into account technological feasibility and must not significantly increase noise or adversely affect safety.
- Emissions standards are enforced by FAA through aircraft and engine certification.

Note............There are currently no active or planned exhaust gas emission standards applicable to aviation reciprocating engines. On the other hand, turbine aviation engines are subject to emission standards.
Summary
Environmental Considerations

- The EPA has not proposed to ban leaded AVGAS
- The EPA are at the first step of a long process and have made no decisions
- EPA is committed to working closely with FAA, States, Industry and user groups to keep piston-engine aircraft flying in an environmentally acceptable and safe manner throughout the U.S.
- The EPA cannot take unilateral action (nor does it desire to) ban lead without FAA and public involvement
The Solution?

The industry/government collaborative effort known as the Piston Aviation Fuels Initiative (PAFI)

Funded by congress, FAA and industry in-kind support
Research, Development, Implementation and Transition Must Be a Collaborative Effort

No one can do this alone

Consensus and the marketplace must drive the solution and yet the marketplace is broken/constrained

Fuel must be affordable and satisfy the existing fleet to the greatest degree possible
PAFI Mission

“The mission of PAFI is to evaluate candidate unleaded replacement fuels and identify those fuels best able to technically satisfy the needs of the existing aircraft fleet while also considering the production, distribution, cost, availability, environmental and health impacts of those fuels.”
PAFI Overview

PAFI is a robust joint government/industry initiative established at the request of a broad cross section of the aviation and petroleum industries and consumer representatives.

- Formed pursuant to the recommendations of the UAT ARC Final Report.
- Process for the identification, evaluation and deployment of the most promising unleaded replacements for 100LL that technically satisfy the needs of the existing aircraft fleet.
- Considers production, distribution, cost, availability, environmental and health impacts.
- Goal is data to support FAA *fleetwide authorization* and ASTM specification.
PAFI Funding

- President’s Budget Request Shows Full Funding for Unleaded Avgas Program through 2018
  - Annual FY Budget Request Approximately $6 million
- Congress has authorized $6 million in fiscal year 2015
  - Funding supports the PAFI test program at the FAA William J. Hughes Technical Center and outside contractors
- Industry In-Kind Support
  - Fuel development and supply for testing program
  - Technical expertise for qualification and testing methods
  - Equipment and services for test program
  - Program oversight and management
PAFI Steering Group (PSG)

**Purpose**

- Facilitates, coordinates, expedites, promotes, and oversees the PAFI program
- Coordinates resources and support necessary to execute the program
- Engages industry stakeholders for allocation of expertise and resources to support task groups and the PAFI test program

**Members**

- AOPA – Aircraft Owners and Pilots Association
- API – American Petroleum Institute
- EAA – Experimental Aircraft Association
- GAMA – General Aviation Manufacturers Association
- NATA – National Air Transportation Association
- NBAA – National Business Aviation Association
- FAA - Federal Aviation Administration
PAFI Support Groups

**Technical Advisory Committee (TAC)**
- Reports to PAFI Steering Group (PSG)
- Membership represents aviation product and fuel manufacturers
- Venue to provide industry “in-kind” support – technical & equipment

**Technical Evaluation Committee (TEC)**
- Reports to FAA
- FAA consultants and employees vetted for COI within areas of expertise necessary to evaluate fuels to criteria
- Responsible for Phase I and Phase 2 fuel evaluation & selection

Distinct and Separate Support Groups with **NO** interconnections
Key Takeaways

• Piston Aviation Fuels Initiative (PAFI)
  – Implemented, funded and in process
  – Fleet-wide approval is the primary goal
  – 17 fuels from 6 offerors entered the program July 2014
  – FAA identified 4 fuels from 3 offerors entered Phase 1 Sept. 2014
  – Phase 2 to begin Jan. 2016
  – Completion of PAFI - 2018
  – Supported and funded by Congress and FAA
  – PAFI is not “picking” a fuel but rather qualifying the best fuels for use

• Supply of current leaded avgas remains stable
Path To Unleaded Avgas – Where we Are

PAFI Program July 21, 2015

Implementation of ARC Recommendations

Jan 31 2011- ARC Charter Signed by FAA Administrator

2012 FAA Creates AIR-20/AIR-21

2012 PAFI Steering Group (PSG)

June 2013 FAA SIR Released

March 2015 Phase 1 Test Program Started

ARC Deliberations

July 2010– Oshkosh, GA Coalition Asks FAA to take Leadership Role to Form Public-Private Partnership

2011 - Feb 2012- UAT ARC Final Report & Recommendations Released

2014 PAFI TEC & TAC Implemented

July 2014 Industry SIR Proposals for UL AVGAS

Phase 1 Fuels Selected

2015

2014

2013

2012

2011

2010
FAA Technical Center’s Role in PAFI Test Program

Pre-Screening Phase

Offeror -> Pre-Screening Data -> FAA Technical Evaluation Committee

PASS -> OTA

Rejected -> Pre-Screening Data

Testing at FAA Tech Center

Phase 1 (Fuel Testing)

Phase 1 Data -> FAA Tech Evaluation Committee

PASS -> OTA

Rejected -> Phase 1 Data

Phase 2 (Equipment Testing)

Phase 2 Data -> FAA Tech Evaluation Committee

PASS -> OTA

Rejected -> Phase 2 Data

390 gals of fuel each

Tens of thousands of gals of fuel each

Selected Offerors

Selected Offerors

Tens of thousands of gals of fuel each

OTA

OTA

PAFI Program July 21, 2015
# Fuel Delivery and Handling – Phase 1

<table>
<thead>
<tr>
<th>EXAMPLE ONLY</th>
<th>Formulation #</th>
<th>Overall Fuel Quantity (gals)</th>
<th>GCxGC MS Fuel Quantity (ml)</th>
<th>FAA TC Lab Testing Fuel Quantity (gals)</th>
<th>SWRI Emissions Testing (gals)</th>
<th>Dixie Services Lab Testing Fuel Quantity (gals)</th>
<th>Purdue Rig Testing Fuel Quantity (gals)</th>
<th>Purdue Material Comp Lab Fuel Quantity (gals)</th>
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<tr>
<td>Detonation/ Emissions</td>
<td>$X_1$</td>
<td>50</td>
<td>10 ml</td>
<td>35</td>
<td>10</td>
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<tr>
<td>Materials Compatibility</td>
<td>$X_2$</td>
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<td>Rig No. 1 Low Temp Fuel Flow Ability</td>
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<td>5</td>
<td>25</td>
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<tr>
<td>Rig No. 2 Carburetor Icing</td>
<td>$X_4$</td>
<td>30</td>
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<td>10</td>
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<tr>
<td>Rig No. 4 Storage Stability</td>
<td>$X_6$</td>
<td>30</td>
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<td></td>
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<td>30</td>
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<td>Rig No. 5 Cold Storage</td>
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<tr>
<td>Rig No. 6 Hot Surface Ignition</td>
<td>$X_8$</td>
<td>10</td>
<td>10 ml</td>
<td></td>
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<td>5</td>
<td>5</td>
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</table>

- Samples consolidated into blinded stainless steel drums or glass vials for independent lab and in-house lab testing.

Overall Fuel Quantity: 390
Think This Is Just About Octane?

• Octane requirement is just the tip of the iceberg
  – Avgas has many qualities necessary to control adverse outcomes in our aircraft and engines
  – Evaluating the impact of completely new fuel chemistry on the full history of aircraft production is an immensely complicated undertaking
FAA Technical Center Test Program

Phase I – Lab Tests, Emissions & Toxicology Assessments

Work Product – Evaluation of candidate fuels for potentially show stopping issues

- Chemical makeup
- Performance properties
- Establish credible and peer-reviewed test protocols for ascertaining necessary fit-for-purpose data
- Fit for purpose testing across the ranges allowed by the fuel formulations (worse case formulations)
- Evaluate emissions and toxicology properties
- Data from Phase 1 will be used to evaluate the business case for candidate fuel production, distribution and availability to consumers
Fuel Property Laboratory Testing

– Final agreed-to laboratory test methods for specific fuel property measurements

– Dixie Services Inc. awarded two-year contract with FAA WJHTC for laboratory services
  • Identify traditional fuel properties for each candidate fuel
    – Density
    – Vapor Pressure
    – Freeze Point
    – Distillation Curve
    – Corrosivity
    – Flash point
    – And many others
Fit-for-Purpose Rig Testing

– PEGASAS FAA Center of Excellence Contract
  Awarded to Purdue University, Sept. 02, 2014

• Stage 1, Rig Design/Build – December 2014
• Stage 2, Rig Testing – March 2015
  – Rig #1, Low Temperature Flow Ability
  – Rig #2, Carburetor Icing
  – Rig #3, Dynamic Fuel System
  – Rig #4, Storage Stability
  – Rig #5, Cold Storage
  – Rig #6, Hot Surface
Rig #1, Low Temperature Flow Ability

Evaluate performance changes in hardware with cold fuel.
Rig #2, Carburetor Icing

Evaluate any significant difference between a baseline 100 LL fuel and the candidate fuels regarding the formation of carburetor ice.

Purdue University test stand. Test Method Development sponsored by the Coordinating Research Council Project No. AV-17-13
Rig #3, Dynamic Fuel System

Assessing that there is no unexpected or premature wear, a rig capable of flowing fuel in a cyclical manner through typical aircraft hardware.
Rig #4, Storage Stability

Evaluate the behavior of fuel in a tank over time. Storage in a 43 °C oven and storage in a tank under hot ambient conditions will be conducted.
Rig #5, Cold Storage

Determine how the fuel will behave, especially with respect to separation as the fuel is cooled. Temps -20/-20/-40/-50/-58degC
Rig #6, Hot Surface

Evaluate any propensity of the fuel to create build-up, for example on the engine manifold during shut down, and to develop an understanding of hot surface ignition.
Materials Compatibility Testing

• Baere Aerospace via PEGASAS to FAA WJHTC
• Test procedures and materials lists being finalized
  – Nonmetallics
  – Metallics
  – Fabric
  – Composites
  – Coatings
  – Distribution network materials
• Industry in-kind support for donation of materials and components for materials compatibility and fuel system test rigs
  – Textron
  – Lycoming
  – Continental
  – Cirrus
Initial Engine Detonation Testing

- Limited in scope
- To be used for Phase 2 entrance evaluation
- Two power settings: Takeoff and 75% power
- Baseline 100LL included
- Lycoming IO-540-K Engine
  - Engine model used in extensive CRC engine testing
  - 6 cylinder
  - 300 BHP
  - Critical engine
Engine Out Emissions/Ecological Assessment

• FAA WJH Technical Center exhaust engine-out emissions console.
  – Total Hydrocarbons (THC)
  – Oxides of Nitrogen (NO\textsubscript{x})
  – Sulfur Dioxide (SO\textsubscript{2})
  – Carbon Dioxide (CO\textsubscript{2})
  – Carbon Monoxide (CO)
  – Oxygen (O\textsubscript{2})
  – Particulates

• Limited engine cycle:
  – Low power, full-rich fuel mixture (e.g. idle and taxi)
  – Mid power, full-rich and lean fuel mixture (e.g. approach)
  – High Power, full-rich mixture (e.g. takeoff)

• Environmental/Toxicology Literature Search – An additional assessment identifying any issues in available literature and references for each of the major fuel components that differ from the community experience with 100LL, along with the experience regarding the use of components in additional modal transportation fuels will be summarized in a final research paper.
GCxGC - Mass Spectrometer

- Evaluate and verify the exact chemical makeup of each candidate fuel
- Used to validate and establish baseline for all Phase I test results
- GCxGC testing is being performed in addition to the ASTM D6733 High Resolution GC, to evaluate the validity of the high resolution GC analysis

Pictures were accessed from SHIMADZU.com on 12/5/14.
FAA Technical Center Test Program

**Phase II – Full Scale Engine & Aircraft Testing**

**Work Product** – *Data packages from full scale engine & aircraft testing which support ASTM & FAA Approval*

- Fuels will be tested at the engine and aircraft level to evaluate their suitability across as much of the existing fleet as possible - multiple fuels in multiple engines and multiple aircraft
- Data collected from this testing will generate data that can be used to support the fleet wide authorization of aircraft and engines to operate on the replacement unleaded fuels
- Data from the Phase I and Phase II testing will support ASTM Production Specification
“Cloud” GA Recip Powered Fleet
Objectives

- Piston Engine Fleet Impact Metrics
- Aircraft Fleet Impact Metrics
- Phase II Engine & Aircraft Models for Testing
- Engine & Aircraft Master Test Plan Phase II
- Engine Test & Analysis Plans
- Aircraft Test & Analysis Plans
- GA Piston Fleet (GAPF) Model
- Projected Fleet Coverage Phase II Test Results
PAFI Phase 2 Testing

Engine Test Articles:
• Engine Range, from Carbureted Four Cylinder to Turbocharged/Fuel Injected Six Cylinders
• Includes Representative Radial Engines

Engine Test Matrix:
• Detonation Testing
  – Naturally Aspirated and Turbocharged Engines
  – Includes Fuel Mixes, to Evaluate Phased Deployment
  – Altitude Simulation
• Durability Testing
  – Standard Part 33 Block Test
  – Mission Profile Test
• Performance Testing/Mapping
• Operations Testing, Propeller Test Stand
• Propeller/Crankshaft Vibration Testing, Propeller Test Stand
PAFI Phase 2 Testing

Aircraft Test Articles:
- Aircraft Range; Two Place Light Trainers to High Performance Twins and Rotorcraft
- Includes Breadth of Engine Test Articles

Aircraft Test Matrix:
- Hot Fuel/Weather
- Cooling Climb
- Inflight Restarts
- Engine Handling Characteristics
- Carburetor Icing/Deicing
- Continued Airworthiness/AFM Procedures
- Function and Reliability
Fleet Wide Authorization

Fleet-wide authorization is the **PRIMARY GOAL OF PAFI**

- Approach will not result in classic engine/airframe specific approvals, as there will be no applicant, and no certificate issued
- Plan to determine and publish eligibility lists of engines/aircraft that can utilize the new unleaded AVGAS formulation(s)
- FAA and industry are currently working with Congress to expand or creating new statutory authorization for fleet wide transition

Approach and implementation is fuel dependent

- Fuel properties & composition
- Impact on engine and aircraft models

Plan to publish eligibility lists in the Federal Register
PAFI Takeaway Points

• FAA/Industry Piston Aviation Fuels Initiative (PAFI)
  – Purpose:
    • Facilitate transition to unleaded replacement Avgas with least impact on existing fleet
    • Primary objective is FAA determination of aircraft and engine eligibility for replacement unleaded fuels
  – Status & Milestones:
    • 5-Year Program Under Way and Funded by Congress & Industry Contributions
    • July 2014: 17 candidate fuels from 6 offerors entered the program
    • Sept. 2014: 4 fuels from 3 offerors accepted into Phase 1
    • December 2014 - November 2015 – Phase 1 test program
    • Jan. 2016: Qualified fuels to enter Phase 2 evaluation
    • Dec. 2018: Final fuel(s) complete PAFI testing to support fleet-wide “approval”

• PAFI is a robust industry-government collaborative initiative
  • Crucial to establishing viable marketplace for unleaded fuel

• Program is on schedule and anticipated to stay that way
Next Few Years

- PAFI working an aggressive and ambitious timeline
- EPA timing regulatory actions in harmony with PAFI timelines
  - EPA Endangerment Finding – NPRM 2017, Final Rule 2018
  - Aircraft Lead Emissions Standard – 2018 or thereafter
- FAA must respond to EPA action to meet lead emissions standard – will require unleaded fuel
  - Anticipated 2019 or thereafter
- Availability of leaded avgas remains stable and is projected to be so through the transition
  - Industry working closely with existing lead supplier and fuel industry to coordinate orderly transition from leaded to unleaded fuel
- AIR-20 continues to support applicants that approach the FAA directly for approvals of alternative fuels on specific models of engines and aircraft
Conclusion

“Ultimately it is everyone’s goal that the piston aviation fleet moves efficiently and economically to a viable and safe unleaded future. The PAFI program provides a sound process to ensure that this goal is achieved with a minimum of disruption to the general aviation industry and with the greatest likelihood of marketplace success.”

Reference PAFI Whitepaper Nov 2013
Piston Aviation Fuel Initiative
Links

FAA PAFI Website
http://www.faa.gov/about/initiatives(avgas/)

FAA Contracts SIR Link
https://faaco.faa.gov/index.cfm/announcement/view/15840

FAA Press Release July 10, 2014

End of Presentation
Questions?