COMMENTS OF THE GENERAL AVIATION AVGAS COALITION

ON THE ADVANCE NOTICE OF PROPOSED RULEMAKING ON LEAD EMISSIONS FROM PISTON-ENGINE AIRCRAFT USING LEADED AVIATION GASOLINE

EPA DOCKET NO. EPA–HQ–OAR–2007–0294

# I. INTRODUCTION

On April 28, 2010, the Environmental Protection Agency ("EPA") published in the Federal Register an "Advance Notice of Proposed Rulemaking on Lead Emissions from Piston-Engine Aircraft Using Leaded Aviation Gasoline" (the "ANPR"). 75 Fed. Reg. 22440. The General Aviation AvGas Coalition (the "Coalition") respectfully submits the following comments on the ANPR.

The Coalition is comprised of associations that represent industries, businesses, and individuals that would be directly impacted by any finding made by the EPA in regard to lead emissions from piston-engine aircraft, corresponding aircraft emissions standards, and related changes to the formulation of aviation gasoline. Coalition membership includes the Aircraft Owners and Pilots Association ("AOPA"), the Experimental Aircraft Association ("EAA"), the General Aviation Manufacturers Association ("GAMA"), the National Air Transportation Association ("NATA"), the National Business Aviation Association ("NBAA"), the American Petroleum Institute ("API") and the National Petrochemical and Refiners Association ("NPRA"). Together, these organizations represent general aviation aircraft owners, operators, and manufacturers, and the producers, refiners, and distributors of aviation gasoline.[1]

Since the establishment of the first National Ambient Air Quality Standard ("NAAQS") for lead in 1978, the general aviation and petroleum industries have been committed to safely reducing lead emissions from piston powered aircraft. Today, 100 octane low lead ("100LL") aviation gasoline (or "avgas") contains 50 percent less lead than it did when the lead NAAQS were first introduced, dramatically reducing lead emissions from general aviation. In addition, the general aviation industry is aggressively working to further reduce the lead content of avgas, by an additional 20 percent from the already low 100LL standard. Ultimately, the general aviation community is committed to an unleaded future and has engaged in extensive research seeking a feasible unleaded alternative to today's leaded aviation gasoline. However, the technical challenges of removing lead from aviation gasoline are formidable. Despite extensive efforts, no unleaded replacement has been found and approved that provides adequate and comparable safety and performance to 100LL. But work on this important issue continues and is accelerating, with new efforts to study and develop alternative aviation fuels.

While the aviation and petroleum industries are committed to seeking near-term additional reductions in the lead content of aviation gasoline, the ANPR concerns the Coalition for several reasons. First, the EPA is not actually obligated to make any determination on lead emissions from aircraft engines, as asserted in the ANPR. Second, any such finding would be premature because—as the EPA itself observes—the EPA currently lacks sufficient data to make a careful, reasoned determination. Third, what limited data and modeling do exist indicate that lead emissions from piston engine aircraft do not cause or contribute to any violation of the new, protective lead NAAQS. Finally, ongoing efforts to reduce lead content of avgas and new lead emissions data are likely to alter the EPA's analysis of lead emissions from piston engine aircraft. Given the widespread impact of the actions described in the ANPR, any determination related to lead emissions from piston-engine aircraft must be supported by sound and complete data. As explained in the following comments, the Coalition does not believe that the present body of data is adequate to support any such finding.

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[1] Appendix A contains additional information about Coalition members.

## II. BACKGROUND

### A. Regulatory History

Under Section 231 of the Clean Air Act ("CAA"), the EPA has the authority to regulate aircraft emissions. In October, 2006 the environmental group Friends of the Earth ("FOE") filed a "Petition for Rulemaking Seeking the Regulation of Lead Emissions from General Aviation Aircraft Under § 231 of the Clean Air Act." In response to that petition, the EPA issued the ANPR on April 28, 2010. 75 Fed. Reg. 22440. While the EPA has yet to promulgate lead emissions standards specific to aircraft engines, lead emissions are already subject to extensive regulation under the CAA.

Through a series of actions beginning in 1973, the EPA reduced and then ultimately eliminated lead from automotive gasoline in 1996.[2] In 1976 the EPA listed lead as a "criteria pollutant" and then issued the first NAAQS for lead in 1978.[3] The aviation industry responded by reducing the maximum lead content of aviation gasoline by 50 percent to the present 100LL standard in use today. As a result of these actions, we have witnessed a "dramatic improvement" in air quality, [4] and a 99 percent decrease in total lead emissions—from 74,000 tons in 1980 to 2,000 tons in 2008.[5] And since 2008, lead emissions from avgas have dropped by another 28 percent, to approximately 550 tons per year.[6]

In addition to this sharp decline in lead emissions, the EPA recently strengthened the NAAQS for lead by a factor of ten.[7] 73 Fed. Reg. 66964 (Nov. 12, 2008). The new lead NAAQS are the result of a four-year effort during which the EPA conducted extensive analysis of the human health and ecological risks associated with lead, including "full-scale human exposure and health risk assessments." 73 Fed. Reg. 66966-68. As required by the CAA, the resulting NAAQS were set without regard to costs and at a level that is protective of human health, including sensitive groups, "with an adequate margin of safety." CAA § 109(b); 42 U.S.C.A. § 7409(b). In promulgating the new NAAQS, the EPA discussed this requirement at length and ultimately concluded that the new lead NAAQS "standard of 0.15 μg/m3 . . . is requisite to protect public health, including the health of sensitive groups, with an adequate margin of safety." 73 Fed. Reg. 67006. In the recent ANPR, there is no evidence that lead emissions from avgas have caused any violation of this new, highly protective standard.[8]

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[2] This process began with EPA rulemaking and culminated with a Congressional ban in 1996. *See Regulation of Fuels and Fuel Additives*, 38 Fed. Reg. 1254 (Dec. 4, 1973); *Regulation of Fuels and Fuel Additives; Gasoline Lead Content*, 50 Fed. Reg. 9386 (March 7, 1985); *Prohibition on Gasoline Containing Lead or Lead Additives for Highway Use*, 61 Fed. Reg. 3832 (Feb. 2, 1996).
[3] *See* 43 Fed. Reg. 46246 (Oct. 5, 1978).
[4] 75 Fed. Reg. 22446.
[5] EPA, *Air Quality Trends, available at* http://www.epa.gov/airtrends/aqtrends.html.
[6] 75 Fed. Reg. 22446. At present levels, lead emissions from avgas represent less than one percent of total 1980 lead emissions.
[7] EPA lowered primary lead NAAQS standard from 1.5 micrograms per cubic meter (μg/m3), to 0.15 μg/m3. The prior standard had been in effect since 1978.
[8] *See* 75 Fed. Reg. 22465-67 (discussing "The Lead NAAQS and Lead Emissions From Piston-Engine Aircraft").

## B. Statutory Framework

Section 231 of the CAA grants the EPA authority to make findings related to emissions of air pollutants from aircraft, and to establish aircraft emissions standards in consultation with the Federal Aviation Administration ("FAA"). *See* CAA § 231, 42 U.S.C.A. 7571. This structure grants initial authority to the EPA to make endangerment findings, establishes a collaborative process by which the EPA consults with the FAA to establish emissions standards, and ultimately requires the FAA to implement and enforce the emission standards by prescribing fuel and fuel additive standards. Each of these three steps constitutes a distinct rulemaking process:

> <u>Step 1</u>: The EPA may make a finding that a particular air pollutant emitted from aircraft engines "causes, or contributes to, air pollution which may reasonably be anticipated to endanger public health or welfare." CAA § 231(a)(2)(A), 42 U.S.C.A. 7571(a)(2)(A).
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> <u>Step 2</u>: Once the EPA determines that a pollutant endangers public health or welfare, the EPA must consult with the FAA to establish aircraft engine emission standards. CAA § 231(a)(2)(B)(i); 42 U.S.C.A. 7571(a)(2)(B)(i). Emission standards cannot "significantly increase noise and adversely affect safety." CAA § 231(a)(2)(B)(ii); 42 U.S.C.A. 7571(a)(2)(B)(ii). The President may veto any standard that the Secretary of Transportation finds would create a hazard to aircraft safety. CAA § 231(c); 42 U.S.C.A. 7571(c).
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> <u>Step 3</u>: The FAA is responsible for prescribing and enforcing fuel standards to implement any emissions standards promulgated by the EPA under CAA Section 231. *See* 49 U.S.C.A. 44714. This requires the FAA to promulgate new fuel standards after the EPA creates emission standards under the CAA.

The ANPR represents step one in the above process. While the EPA must involve the FAA in steps two and three, nothing prevents the EPA from seeking data, guidance, or other information from the FAA at the endangerment finding stage.

## C. The Societal and Economic Impacts of General Aviation and Piston-Engine Aircraft

General aviation (or "GA") is a key component of our nation's transportation infrastructure and economy. There are 5,261 public-use airports that can be directly accessed by general aviation aircraft—more than ten times the number of airports served by scheduled airlines. These public use airports are the only available option for fast, reliable, flexible air transportation to small and rural communities in every corner of the country. General aviation directly supports jobs in these communities, provides a lifeline for small to mid-sized businesses, and provides critical services to remote cities and towns, particularly in time of natural disaster or crisis. As a result, general aviation is uniquely situated to serve some of the public's most crucial transportation needs.

The economic impact of general aviation is also significant. General aviation contributes to the U.S. economy by creating output, employment, and earnings that would not otherwise occur. Direct impacts, such as the purchase of a new aircraft, multiply as they trigger transactions and create jobs elsewhere in the economy (*e.g.*, sales of materials, electronics, and a wide range of other components required to make and operate an airplane). Indirect effects accrue as general aviation supports other facets of the economy, such as small business, rural economies, and tourism. Directly or indirectly, general aviation accounted for over 1.25 *million* jobs in 2005 (with collective earnings exceeding $53 billion) and contributed over $150 *billion* to the U.S. economy.[9]

Any regulatory action by the EPA related to lead emissions will directly affect general aviation. Without appropriate consideration of aviation safety, technical feasibility, and economic impact, a transition to an unleaded replacement for 100LL could have a significant impact upon the viability and long-term health of the general aviation industry. To gauge this impact, the general aviation engine and aircraft manufacturers are currently performing a fleet-wide assessment to determine the effects of any transition to currently available lower-octane unleaded avgas fuels.[10]

Initial findings, based on an analysis of 72.2 percent of the FAA type certified active fleet of piston engine aircraft, indicate that approximately 57,000 aircraft would be unable to operate on the lower-octane unleaded avgas. This represents 34 percent of the fleet, including most twin-engine airplanes. While some of these aircraft and engines could be modified to operate safely with a lower-lead fuel, this would require either a reduction in horsepower or some degree of engine replacement.[11] Importantly, a large portion of these aircraft are operated in business or commercial service with high utilization. As a result, aircraft unable to operate on the lower-octane unleaded avgas represent a high proportion of total general aviation flight hours. This translates directly to a significant economic impact upon general aviation and other related sectors, such as airport operations, sales of fuel, maintenance, parts, and services to these aircraft operators.

In order to better quantify and understand these impacts, an analysis of engines and aircraft by make/model is currently being cross-referenced with FAA activity data regarding general aviation operations in 2008. This will allow quantification of flight hours, type of operation, and fuel consumption. The resulting impact analysis will provide an important baseline on the safety, technical, and economic effects associated with transitioning to potential replacements for the current 100LL standard. Results are expected within the next several months. Once complete, these results will be provided to the EPA for consideration in regard to the ANPR and any future aircraft engine emissions standards.

## D. Historical and Current Efforts to Reduce Lead in Avgas and Related Safety Considerations

There is no demonstrated unleaded replacement for 100LL avgas that meets the safety and operational requirements of the entire fleet. Unlike the transition away from leaded gas in

[9] MergeGlobal, Inc, *General Aviation's Contribution to the U.S. Economy*, at 2 (May, 2006), *available at* http://www.gama.aero/files/ga_contribution_to_us_economy_pdf_498cd04885.pdf (accessed August 27, 2010). These conservative figures do not measure all of general aviation's significant net benefits to the U.S. economy.

[10] A lower octane replacement for 100LL would be considered a worst case scenario because octane rating is a key property of avgas having the greatest impact upon engine power and aircraft performance. High performance aircraft engines require a minimum of 100 octane in order to safely produce rated horsepower.

[11] These replacements would entail a bigger engine displacement with lower compression ratio.

automobiles, performance issues in aircraft have life-and-death consequences for pilots and passengers. Those living underneath flight paths also face risks associated with potential accidents caused by poorly performing aircraft. While the general health risks associated with lead are well documented, we must also ensure the safe operation of approximately 163,000 general aviation aircraft.[12]

There have been significant historical and current efforts to develop an unleaded high-octane aviation gasoline that maintains the properties necessary for the safe operation of aircraft engines. Tetra-ethyl lead ("TEL") is a lead compound that raises octane, which reduces gasoline's tendency to suddenly and instantaneously ignite from compression (also known as detonation or "knocking") during a reciprocating engine's combustion cycle. Sustained detonation can cause catastrophic engine failure. There is a direct relationship between the amount of horsepower a high-performance aircraft engine can produce and the octane level it requires to operate safely. In addition, the alloys used in aviation engine construction are chosen for their durability and synergistic relationship with the lubricating properties of lead. As a result, engine wear and maintenance issues arise in the absence of leaded fuel. Increased maintenance has an economic impact, but also raises safety concerns due to the increased potential for engine component failure. The current avgas specification, ASTM D910, defines the acceptable limits for several physical and performance properties necessary for an aviation gasoline to ensure safe operation of aircraft across a broad range of very demanding conditions. The TEL additive and high-octane rating it provides is just one of several safety issues that must be addressed when developing a lower-lead or unleaded alternative to 100LL. Appendix B provides a more complete discussion of these and other safety issues related to avgas formulation and impact upon engine and aircraft safety certification.[13]

With these and other safety considerations in mind, the aviation industry has engaged in efforts to reduce lead emissions from avgas. As the public became concerned with the health risks associated with lead emissions in the early 1970's, the general aviation industry responded by engaging in an extensive research effort. That effort resulted in a 50 percent reduction in the lead content of avgas and the 100LL standard in use today.

Testing of alternative general aviation fuels has been conducted at the FAA Aviation Fuel and Engine Test Facility ("AFETF") in cooperation with the Coordinating Research Council ("CRC") unleaded avgas research group, and individual refiners. Although no "drop-in" replacement for 100LL avgas has been identified and approved for use in the entire fleet, much has been learned about the effects of lead in avgas and the impact of its removal on engine performance and durability. The FAA AFETF and CRC have published technical reports on the results of unleaded avgas research activities and more data is forthcoming.

The CRC is continuing efforts to develop an unleaded alternative to 100LL and has undertaken an evaluation of whether a near-term reduction in lead emissions from general aviation is possible by further reducing the amount of lead in avgas. The FAA is also continuing to support the AFETF's research on alternative fuels for general aviation. The President's

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[12] *See* FAA, *General Aviation and Part 135 Activity Surveys – CY 2008* (2009), *available at* http://www.faa.gov/data_research/aviation_data_statistics/general_aviation/CY2008/.

[13] *See* Appendix B for a more complete discussion of these and other safety issues related to avgas formulation.

budget for the 2011 fiscal year proposed $2 million annually for five years to fund additional research and development of alternative general aviation fuels. Congress has also expressed support for this research—the House and Senate Transportation Appropriations Bills fully fund the FAA's research program on alternative fuels for general aviation and specifically recognizes its importance and requests FAA to detail in future budgets the resources necessary to implement a transition to unleaded avgas. Appendix C provides additional details on these and other efforts to reduce or eliminate lead in avgas.

## III. COMMENTS ON THE ADVANCE NOTICE OF PROPOSED RULEMAKING

The ANPR indicates that the EPA is focused on a perceived obligation to make an endangerment finding related to lead emissions from avgas. However, such a determination is not required by the FOE petition or the CAA. Moreover, any such finding would be premature because the EPA lacks sufficient data to make a careful, reasoned determination at this time. There is limited data and modeling on lead emissions from avgas, and current data indicates no violation of the new, highly protective lead NAAQS. When additional information becomes available as a result of new monitoring requirements and additional fuel studies discussed above, the EPA will be in a better position to evaluate lead emissions from piston-engine aircraft. In the meantime, the general aviation community stands ready to support additional data collection and research efforts.

### A. EPA Is Not Required to Make an Endangerment Finding

Neither the CAA nor the FOE Petition requires the EPA to make an endangerment finding. First, nothing in the Clean Air Act requires the EPA to make a finding related to lead emissions from avgas.[14] In fact, Section 231 of the CAA begins by stating that the EPA "shall commence a study and investigation of emissions of air pollutants from aircraft" to determine the affect of such pollution and the "technological feasibility of controlling" aircraft emissions. CAA § 231(a)(1). Second, the ANPR is the EPA's response to a petition that requests that the EPA *either* make a finding that emissions from leaded avgas represent a danger to human health and the environment *or* commence a study to enable the Agency to make such a determination. 75 Fed. Reg. 22444. As discussed below, continued study is necessary given the limited data currently available to the EPA and the lack of any showing that lead emissions from avgas contribute to any violation of the NAAQS. Accordingly, a decision to engage in continued study and analysis of this important issue is a correct and logical response to the FOE Petition.

### B. EPA Has Inadequate and Insufficient Data to Make an Endangerment Finding

1. Current Monitoring Data is Limited and Inadequate

The ANPR sets out the information that the EPA has available to consider while making any finding under Section 231 of the CAA. The ANPR also makes it clear that the Agency currently has inadequate or insufficient information from which it could find that leaded avgas endangers the public health or welfare.

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[14] The EPA has recently affirmed the discretionary nature of findings under Section 231 of the CAA. *See* EPA's Motion to Dismiss, *Center for Biological Diversity v. U.S. EPA*, No. 10-985 (D.C. Cir. Aug. 20, 2010).

The EPA acknowledges that its "current database for ambient lead concentrations . . . at airports is severely limited." 75 Fed. Reg. 22459. Ambient air concentration data for lead is limited to "samples collected on or near five airports," two of which are located in Canada. 75 Fed. Reg. 22457. Beyond these five data points, the EPA currently lacks any data on lead emissions at or around airports. In addition, there has been no significant analysis of background levels of lead in and around airports, which typically are areas with relatively intensive past road traffic (using leaded fuel), or any discussion of other potential contributors to ambient lead concentrations from nearby industrial activities, surface disturbances, and other sources.

In addition to a lack of monitoring data, the ANPR identifies only a single study that has evaluated lead concentrations at airports. The study, at the Santa Monica municipal airport in Santa Monica, CA "is the only study to date . . . that provides ambient concentrations relevant for comparison to the Lead NAAQS." *Id.* While the EPA is currently developing a modeling approach based on this study to evaluate lead concentrations at other airports, that model is not yet complete and has not been validated against actual monitoring data at other airports. And before any model based on the Santa Monica study can be applied to other airports, the study itself recommends that the EPA conduct extensive additional research, including a survey on landing and takeoff operations, collecting hourly data on piston-engine aircraft operations, and compiling information on stationary sources within 20 kilometers of each airport that the model is applied to.[15] Without this additional data, the EPA is currently unable to accurately apply the Santa Monica study, or a model based upon it, to other airports.

As the ANPR notes, additional data is forthcoming as a result of new lead monitoring requirements and the EPA is planning new air quality modeling efforts. 75 Fed. Reg. 22465. These activities will help address the deficiencies outlined above. In the meantime, the limited data and modeling available to the EPA makes it difficult or impossible to accurately quantify lead emissions and any contribution that piston-engine aircraft make to ambient lead concentrations.

2. <u>The Current NAAQS of Lead are Protective of Human Health and Welfare and Current Data Shows No Exceedance Due to Aircraft Emissions</u>

The EPA recently lowered the NAAQS for lead by a factor of ten—a 90 percent reduction—to assure protection against lead-related public health and welfare effects. 73 Fed. Reg. 66970–67007 (Nov. 12, 2008). The EPA notes that although there is no definition of "public health" in the CAA, the EPA has looked at "morbidity, including acute and chronic health effects, as well as mortality" when establishing NAAQS. 75 Fed. Reg. 22445. The EPA also notes that the term "welfare" has an expansive definition. *Id.* As discussed above, the EPA gave careful consideration to a broad range of health and welfare effects when establishing the new lead NAAQS in 2008. The EPA ultimately set the lead NAAQS at a level designed to "provide increased protection for children and other at-risk populations." 75 Fed. Reg. 22448.

In the ANPR, the EPA discusses the health and welfare effects of lead in the context of the 2008 lead NAAQS. 75 Fed. Reg. 22447-52. These health and welfare effects are well

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[15] *See* ICF International & T&B Systems, *Development and Evaluation of an Air Quality Modeling Approach for Lead Emissions from Piston-Engine Aircraft Operating on Leaded Aviation Gasoline*, at 72-73 (Feb., 2010) (discussing conclusions of the Santa Monica study).

documented. With its comprehensive and detailed knowledge of these effects derived from nearly forty years of experience with regulating lead emissions, the EPA designed the 2008 lead NAAQS to be protective of human health "with an adequate margin of safety," as mandated by the CAA. 73 Fed. Reg. 67006; CAA § 109(b); 42 U.S.C.A. § 7409(b).

Despite recently lowering the lead NAAQS to this new, highly protective level, the EPA has no data demonstrating that avgas emissions cause or contribute to any violation of the NAAQS. In fact, the only multi-site monitoring analysis that EPA has available, near the Santa Monica airport, shows that there is no exceedance of the revised lead NAAQS, even with the monitor placed where lead concentrations are expected to be the highest. In fact, the monitored lead emissions from that site were 50 percent *below* the revised NAAQS. Monitoring data at four other airports yields a similar result, with no demonstrated exceedance of the lead NAAQS, based on reported average lead concentrations that are approximately 80 percent *below* the lead NAAQS. 75 Fed. Reg. 22457-59

The current NAAQS are designed to be protective of human health with a margin of safety, and the EPA has no data demonstrating that lead emissions from avgas cause or contribute to any exceedance of the lead NAAQS. While the EPA plans to make new attainment and non-attainment designations for lead by January 2012, the EPA is not currently in a position to evaluate any contribution that piston-engine aircraft may make to any non-attainment of those standards, especially given the very limited data and modeling on lead emissions from avgas currently available. Until such time as the EPA has new data confirming that lead emissions contribute to a violation of the lead NAAQS, an endangerment finding is unwarranted and inconsistent with the fact that the newly revised NAAQS are being met.

3. <u>The EPA's Current Lead Emissions Inventory is Insufficient to Support a Cause and Contribute Finding</u>

In addition to finding that air pollution "may reasonably be anticipated to endanger public health or welfare," the EPA must also find that lead from avgas "causes, or contributes to" that pollution. CAA §231(a)(2)(A); 42 U.S.C.A. 7571(a)(2)(A). Even though this "cause and contribute" clause does not contain a "significance" threshold, the EPA must still quantify emissions before determining that they cause or contribute to air pollution.

Despite this requirement, the EPA is currently unable to accurately quantify lead emissions from avgas. In the ANPR, the EPA bases the National Emissions Inventory ("NEI") for lead emissions from avgas on Department of Energy ("DOE") fuel volume estimates. But the sources of that data are unknown and currently unverified, and the EPA states that it is "working to identify the source(s) of the information used to derive DOE fuel volume estimates." 75 Fed. Reg. 22453. Moreover, the EPA "currently cannot estimate the fraction of total lead emissions these estimates comprise since the inventories for all other sources of lead to air are not yet in the draft 2008 NEI." *Id.* In other words, avgas fuel volumes, the corresponding emissions inventory for avgas, and any contribution to total lead emissions from avgas that the EPA relies on in the ANPR are speculative.

The EPA is also basing its current lead emissions estimates and contribution percentages on outdated 2005 data. *Id.* Without an accurate inventory of lead emissions from avgas and an accurate overall lead inventory against which to compare those emissions, it is impossible for the EPA to quantify how these emissions cause, or contributes to, air pollution that could endanger public health or welfare. Until the EPA has more reliable data quantifying lead emissions in general and from avgas in particular, it cannot reasonably support a "cause and contribute" finding.

## C. Additional, Rigorous Study is Required to Support an Endangerment Finding

### 1. Any Finding is Premature Because Additional Data on Lead Emissions is Forthcoming

The EPA's revised lead NAAQS requires extensive state-level monitoring, reporting and air modeling of lead emissions. Approximately 135 of these monitors came online only this year. As the EPA points out in the ANPR, it will not have enough data to make complete lead attainment and non-attainment designations until January 2012. The EPA should wait to obtain this required data and analyses so that it has adequate information on which to base any determination about lead emissions from avgas.

The FAA will also generate additional information that will aid the EPA's analysis. In collaboration with the general aviation community, the FAA has committed to test, adopt, and certify a new aviation gasoline fuel standard as set forth in the 2009-2013 Flight Plan. To further this effort, the President's budget for fiscal year 2011 proposed $2 million annually for five years to fund the FAA's research and development of alternative fuels for general aviation. This effort will generate valuable data on the effects of lead in avgas that will aid the EPA's evaluation of lead emissions from piston-engine aircraft.

### 2. The EPA Should Continue to Work with the General Aviation Industry, the Federal Aviation Administration, and Other Stakeholders

The EPA has solicited public comments and has engaged in open discussions with industry trade associations, the CRC, the FAA, fuel producers, and airframe/engine manufacturers during this rulemaking process. The Coalition appreciates this dialogue and recommends that the EPA continue to work with these and other stakeholders.

By engaging with the general aviation industry, the EPA can gain valuable data to inform current and future regulatory processes related to lead emissions from avgas. For example, efforts are underway to evaluate the feasibility and impacts of converting to an unleaded fuel.[16] While the general aviation industry is willing to continue such efforts and share the results with the EPA, reliable data cannot be developed overnight. Because the general aviation industry is effectively a collection of many large and small businesses, compiling information requires a sustained effort involving many different entities. Recognizing these challenges, the signatories to this petition are willing to share additional data with the EPA as it becomes available. In turn, the EPA should continue to engage with the general aviation industry during this regulatory process.

[16] These efforts and resulting information are discussed above and in Appendices B and C.

In addition to engaging with the general aviation industry, the EPA should work with other government entities that can contribute valuable data and expertise to a study of emissions from piston-engine aircraft. In particular, the FAA has considerable expertise on this issue, as Congress recognized when it made the FAA a partner in the standards-setting process. And while the CAA does not mandate that the EPA include the FAA in a study of aviation emissions, it does require that the EPA consult with the FAA before imposing any new requirements that could impact the safety of general aviation. *See* CAA § 231(a)(2)(B)(i); 42 U.S.C.A. 7571(a)(2)(B)(i). This requirement springs from the FAA's statutory jurisdiction and responsibility over all matters that may affect aviation safety.

To better collect and organize various sources of information, the EPA should create a Federal Advisory Committee that includes members of the general aviation industry, the FAA, and other concerned parties. Given the limited availability of data and studies on lead emissions from avgas, these groups will play a valuable role in collecting, aggregating, and analyzing all available data to ensure that any determination is made using the best possible information. The EPA should also consider engaging the Science Advisory Board ("SAB") to design an appropriate study on lead emissions from avgas. The EPA has extensive experience with this process and routinely utilizes SAB expertise when designing and implementing environmental studies. SAB participation will help to assure that any study or modeling is conducted in a transparent manner and in accordance with accepted scientific methods.

The EPA could further ensure that the roles of all affected governmental and non-governmental stakeholders are considered by engaging in Negotiated Rulemaking under the Administrative Procedure Act. *See* 5 U.S.C.A. §§ 561-570. Negotiated Rulemaking provides a working forum to facilitate consensus and can incorporate a "negotiated rulemaking committee" under the Federal Advisory Committee Act. 5 U.S.C.A. § 565.

By engaging with stakeholders and the SAB, the EPA will ensure that it relies on the best available data and science in a process that is open, collaborative, and able to create consensus across the many stakeholders in this important issue.

3. <u>Additional Data and Analysis is Required to Support OMB Review of this Significant Regulatory Action</u>

As the EPA points out in the ANPR, this is a "significant regulatory action" subject to review by the Office of Management and Budget ("OMB"). 75 Fed. Reg. 22468; Executive Order 12866, 58 Fed. Reg. 51735, Oct. 4, 1993. During this review process, OMB requires an assessment and quantification of the benefits and costs of any EPA determination and of "reasonably feasible alternatives." *Id.* In order to justify any determination related to avgas emissions, the EPA must demonstrate that it has quantified the benefits and costs related to such determination. As discussed above, the EPA currently lacks adequate data to make a full assessment of the costs and potential benefits of any determination. In addition, the EPA has not yet addressed any "reasonably feasible alternatives," such as reducing lead emissions from other sources or further strengthening the generally applicable NAAQS. Accordingly, additional data and analysis will aid the EPA in the OMB review process by helping to demonstrate the costs and benefits of any determination and why that determination is preferable to all other "reasonably feasible alternatives."

### D. Future Considerations Regarding Aircraft Engine Emissions Standards

The ANPR describes considerations regarding emission engine standards and requests comment on approaches for transitioning the piston-engine fleet to unleaded avgas. As the EPA recognized in the ANPR, "[c]onverting in-use aircraft/engines to operate on unleaded aviation gasoline would be a significant logistical challenge, and in some cases a technical challenge as well." 75 Fed. Reg. 22468. In recognition of this challenge and in response to the EPA's request, Appendices D and E provide additional information and recommendations regarding possible future rulemaking by the EPA and the FAA to establish new standards to reduce or eliminate lead emissions from general aviation aircraft, and to transition the in-use fleet to an unleaded avgas.

## IV. CONCLUSION

For the general aviation community, any regulation of aircraft emissions is a safety of flight issue. Small changes to aviation fuel can have life and death consequences for pilots, passengers, and those living underneath flight paths. The EPA has recognized that safety is paramount when addressing aircraft emissions, observing that "there is an added emphasis [in § 231] on the consideration of safety. Therefore, it is reasonable for EPA to give greater weight to considerations of safety in this context than it might in balancing emissions reduction, cost, and energy factors under other [CAA] provisions."[17] The prominence of safety reinforces the need to proceed carefully, and to make a determination only when such action is well supported by data and careful analysis.

The current data set is seriously limited and shows no exceedance of the highly protective lead NAAQS due to aircraft emissions. Additional data that will become available over the next few years will help to provide the EPA with a better understanding of lead emissions from avgas. And the general aviation industry is already engaged in research efforts on lower-lead alternatives to the current 100LL standard. Before making any determination related to lead emissions from piston-engine aircraft, the EPA should collect this new information, design a more comprehensive study, and evaluate avgas emissions using a more comprehensive data set. The EPA should also continue to engage with stakeholders and seek the expertise of the SAB and the FAA. And, by establishing a formal Advisory Committee and engaging in Negotiated Rulemaking, the EPA can facilitate stakeholder involvement and build consensus throughout the rulemaking process. A decision to continue research into this important issue before making any determination is consistent with the Clean Air Act, responsive to the Friends of the Earth Petition, and will help to ensure that the EPA's ultimate decision appropriately protects pilots and the public.

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[17] 70 Fed.Reg. at 69,676 (promulgating new NOx emissions standards for aircraft). The EPA's emphasis on safety was upheld by D.C. Circuit in *National Association of Clean Air Agencies v. EPA*, 489 F.3d 1221 (2007).

*Respectfully submitted,*

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## TABLE OF APPENDICES

# APPENDIX A

## About The General Aviation Avgas Coalition

### The Aircraft Owners and Pilots Association (AOPA)

The Aircraft Owners and Pilots Association is a not-for-profit individual membership organization of more than 415,000 pilots and aircraft owners. AOPA's mission is to effectively serve the interests and needs of its members as aircraft owners and pilots and establish, maintain, and articulate positions of leadership to promote the economy, safety, utility, and popularity of flight in general aviation aircraft. Representing two thirds of all pilots in the United States, AOPA is the largest civil aviation organization in the world.

### The Experimental Aircraft Association (EAA)

The Experimental Aircraft Association is a non-profit individual membership organization of 170,000 pilots and aircraft owners with a wide range of aviation interests and backgrounds. EAA's mission is dedicated to providing aviation access to all who wish to participate. As part of that, EAA is committed to protecting the right to fly and own recreational aircraft, promoting opportunities to experience and enjoy aviation, preserving aviation history and heritage, and preparing for tomorrow and future generations of aviators. EAA has chartered approximately 1,000 Chapters which promote local aviation activities in their communities and regions.

### The General Aviation Manufacturers Association (GAMA)

The General Aviation Manufacturers Association represents over 65 of the world's leading manufacturers of fixed-wing general aviation airplanes, engines, avionics, and components. In addition to building nearly all of the general aviation airplanes flying today, GAMA member companies also operate aircraft fleets, airport fixed-based operations, pilot training, and maintenance facilities worldwide.

### The National Air Transportation Association (NATA)

The National Air Transportation Association, the voice of aviation business, is the public policy group representing the interests of aviation businesses before Congress, federal agencies and state governments. NATA's 2,000 member companies own, operate and service aircraft. These companies provide for the needs of the traveling public by offering services and products to aircraft operators and others such as fuel sales, aircraft maintenance, parts sales, storage, rental, airline servicing, flight training, Part 135 on-demand air charter, fractional aircraft program management and scheduled commuter operations in smaller aircraft. NATA members are a vital link in the aviation industry providing services to the general public, airlines, general aviation and the military.

### The National Business Aviation Association (NBAA)

Founded in 1947 and based in Washington, DC, the National Business Aviation Association is the leading organization for companies that rely on general aviation aircraft to help make their businesses more efficient, productive and successful. The Association represents more than 8,000 Member Companies of all sizes and located across the country.

**The American Petroleum Institute (API)**

The American Petroleum Institute is the only national trade association that represents all aspects of America's oil and natural gas industry. Our more than 400 corporate members, from the largest major oil company to the smallest of independents, come from all segments of the industry. They are producers, refiners, suppliers, retailers, pipeline operators and marine transporters, as well as service and supply companies that support all segments of the industry.

**The National Petrochemical and Refiners Association (NPRA)**

The National Petrochemical & Refiners Association is a national trade association based in Washington, D.C. representing more than 450 members, including virtually all U.S. refiners and petrochemical manufacturers. Our members supply consumers with a wide variety of products used daily in their homes and businesses. These products include gasoline, diesel fuel, home heating oil, jet fuel, lubricants, and the chemicals that serve as "building blocks" for everything from plastics to clothing to medicine to computers and many other products essential to maintaining and improving the nation's quality of life.

# APPENDIX B

## SAFETY AND OTHER CONSIDERATIONS RELATED TO AVGAS REFORMULATION AND REPLACEMENT OF 100LL

Avgas formulation and performance properties have a significant impact upon aviation engine performance and must be suitable for aircraft use under a wide variety of operating conditions. Aircraft/engines are designed and tested for operation using a specific avgas specification/grade and type certificated by the FAA as meeting all applicable minimum airworthiness safety standards. There are many safety and other considerations that must be made related to an unleaded avgas replacement for 100LL, particularly if there is any reformulation affecting the composition and properties of avgas to which the entire in-use fleet of aircraft/engines have been certificated by the FAA. This Appendix provides a summary of the safety considerations related to avgas reformulation and FAA certification of aircraft/engines as well as other considerations related to an unleaded avgas replacement for 100LL.

### A. Safety Considerations Related to Avgas Reformulation

ASTM D910, *Standard Specification for Aviation Gasolines* defines the composition and properties of the following specific types of aviation gasoline for civil use: Grade 80; Grade 91; Grade 100; and Grade 100LL (although 100LL is predominantly the only avgas available at airports today). The following issues are a few of the many additional challenges faced when developing a new avgas standard. Each parameter represents a critical safety of flight characteristic that must be considered in the operation of general aviation aircraft.

1. <u>Octane</u>

Octane is a measure of the anti-detonation (also known as anti-knocking) properties of gasoline which is its resistance to sudden and instantaneous ignition from compression (also known as detonation or “knocking”) during a reciprocating engine’s combustion cycle. Sustained detonation can cause catastrophic engine failure. A high-performance engine has a higher compression ratio and requires higher-octane fuel. The advantage of a high performance aircraft engine is that it provides higher horsepower ratings for a given engine weight.

Most research on a potential replacement for leaded avgas to-date has focused on attaining the 100 motor octane requirement for the fleet of existing general aviation aircraft because it determines the ability for the existing engines to safely use the fuel. A fuel's octane rating has a direct correlation to a given engine's ability to produce its maximum rated power, which in turn affects a number of aircraft safety factors including take-off distance, climb rate, hot weather performance, and load carrying capability. Any reduction in power brought about by a change in the octane rating or energy density of a new fuel requires re-certification of the aircraft and engine by the FAA; a tremendously expensive and labor intensive activity for which neither government nor industry has the capability or resources to complete.

But while octane is a critical consideration, it is only one of many fuel characteristics that affect the development of a safe and viable replacement for 100LL avgas.

2. Distillation Curve

One of the most important and informative properties for engines operating on complex fluid mixtures is the distillation (or boiling) curve of the fuel. Simply stated, the distillation curve is a graphical depiction of the boiling temperature of a fluid mixture plotted against the volume fraction distilled. Distillation curves are used commonly in the design, operation and specification of liquid fuels such as gasoline, diesel fuel, rocket propellant, and gas turbine fuel to ensure proper vaporization of the fuel and good air/fuel mixing prior to combustion. Measurement of the initial temperatures and the examination of the distillation curves can serve as methods to evaluate the operational parameters of fuels, such as cold/hot/altitude start capabilities, fuel system icing, dynamics of acceleration, vapor pressure/susceptibility to vapor lock and carburetor icing.

3. Vapor Pressure

Vapor pressure is a measure of a fuel's volatility, or how readily the fuel will vaporize. Vapor lock occurs when the liquid fuel changes state from liquid to gas while still in the fuel delivery system. This disrupts the operation of the fuel pump, causing loss of feed pressure to the carburetor or fuel injection system, resulting in transient loss of power or complete engine stalling. Restarting the engine from this state may be difficult or impossible. The fuel can vaporize due to being heated by the engine, by the local climate or due to a lower boiling point at high altitude. The higher the volatility of the fuel, the more likely it is that vapor lock will occur. Avgas has a lower and constant vapor pressure compared to automotive gasoline, which keeps avgas in the liquid state at high-altitude, preventing vapor lock.

4. Water Separation and Freeze Point

Water solubility in hydrocarbon fuels is a function of their composition and temperature. For a given composition lower temperatures reduce the solubility of water in the fuel. Current avgas dissolves only a very small amount of water at ambient temperatures. Therefore there is relatively little water to separate and freeze as the fuel cools at altitude. Additionally there are additives that can be used with avgas which partition any water that does separate from the fuel and lower the freezing point of the water.

Freeze point and water shedding are characteristics of a fuel that depend largely on the composition of the fuel. Solids that form from water or fuel freezing can impede flow of fuel through filters and screens, starving the engine and reducing its power or in extreme cases stalling an engine.

Because avgas is a mixture rather than a pure substance, there is not a temperature at which the entire fuel turns from a liquid to a solid. Freeze point for an aviation fuel is the temperature at which crystals begin to form, actually at which the last crystal melts as the fuel is warmed, to avoid super cooling phenomena. Freeze point for avgas should be below the temperature where an aircraft will operate long enough for fuel flow to be impacted by crystal formation from the dry fuel.

Water separation is a particularly important trait in aviation gasolines because the fuel systems are vented to the atmosphere and significant changes in altitude and temperature promotes condensation of water in the fuel tanks which must settle out of suspension readily so that it can be drained prior to flight to prevent loss of power due to water and/or ice contamination..

5. Energy Density / Weight

Energy is the ability to do work. Per kilogram of mass or volume, different substances release different amounts of energy when combusted. In other words they have different energy contents. Energy density can be defined by the amount of energy per gallon or per pound of fuel. The higher the energy density, the more energy may be stored or transported for the same amount of volume or weight. Because aircraft have fixed volume fuel tanks and are limited in total weight for takeoff, both volumetric and gravimetric energy density are important parameters of a new fuel. A lower energy density fuel directly translates to either reduced range, reduced power, or a combination of the two. Increased fuel weight equates to reduced load carrying capability, decreased rate of climb at a given loading or reduced range of the aircraft.

6. Stability

Stability of a fuel can be defined as the resistance or the degree of resistance to chemical change or degradation. When gasoline is not stored correctly over a period of time, gums and varnishes may build up and precipitate from the gasoline. Gums and sediment may build up in the fuel tank, lines, and carburetor or fuel injection components making it harder to start the engine and cause rough operation of the engine. This could be a problem for aircraft as some are typically parked without use for long periods of time. Additionally, because aviation gasoline is not produced and sold in large quantities, fuel is often stored for extremely long periods of time before being delivered to the aircraft for use.

7. Corrosiveness

A fuel's corrosiveness directly relates to the material compatibility issues that such a fuel would have on metal fuel system components including aircraft fuel tanks, fuel lines, and internal engine components.

8. Conductivity

The conductivity of a fuel is a measure of the ability of a fuel to dissipate static electric charge. Conductivity is important because in a low conductivity fuel electrical charges can accumulate and ultimately lead to dissipation in the form of a spark. This in turn is a fire safety hazard. Aircraft naturally build up static charges by virtue of the friction involved in their passage through the atmosphere and the fuel needs to be able to equalize the electrical charges between aircraft components so as to prevent sparking.

9. Toxicity

All hydrocarbon fuels are toxic to one degree or another but aviation gasoline and any future unleaded fuel cannot exhibit any unusual or significantly increased toxicity traits that could affect persons handling the fuel, maintaining the aircraft, or impair flight crews in flight through inhalation of harmful vapors.

10. Composition

Specifications define the composition of aviation gasoline to limit maximum content of certain chemicals in order maintain desired properties and ensure it is suitable for civil aircraft use under a wide variety of operating conditions. For example, D910 limits the total aromatic content which relates to material compatibility issues of certain aircraft fuel system components made from natural rubbers and some polymeric substances

## B. Safety Considerations Related to Aircraft/Engine and FAA Certification

As discussed previously a variety of physical and performance properties necessary for an aviation gasoline such as octane, vapor pressure, distillation curve and water separation must be considered. However, fuel properties are just the beginning of all the considerations necessary to ensure the safe operation of general aviation aircraft. General aviation engines and aircraft are specifically designed, built and tested for operation using a specific avgas specification which is certified by the FAA as meeting all applicable minimum airworthiness safety standards in 14 C.F.R. Federal Aviation Regulations ("FAR").

FAR part 33 prescribes airworthiness standards for aircraft engines including the establishment of engine ratings and operating limitations relating to horsepower, temperatures, pressures, component life and fuel grade or specification. The engine design and construction must minimize the development of an unsafe condition of the engine between overhaul periods which must be demonstrated through rigorous block tests. This includes operation throughout the full envelope of extreme conditions the engine is expected to encounter in service and demonstration of the engines ability to start in extreme cold/hot temperatures and altitudes. Fuel properties such as vapor pressure, freeze point and distillation curve directly affect these engine performance envelopes. The most important performance range for an engine is horsepower and the safety critical limiting factor is detonation. The octane level of avgas is a measure of protection against the onset of detonation so the higher the octane the higher the horsepower that is possible from a particular engine and vice-versa. FAR section 33.47 requires a test program to ensure that an aircraft engine can operate without destructive detonation throughout its full range of operation. In addition, each engine is subject to a prescriptive endurance test and inspection to ensure reliability and continued airworthiness necessary for safety. FAA issuance of an engine Type Certificate which identifies a fuel grade or specification as a limitation constitutes approval of the fuel for that particular make and model of engine.

FAR parts 23 and 27 prescribes minimum airworthiness standards for normal category airplanes and normal category rotorcraft, respectively (which are the aircraft typically powered by piston-engines). This includes demonstration of minimum aircraft performance requirements such as takeoff runway length, climb, speeds and distance over a range of conditions such as maximum weight/payload, maximum outdoor temperatures and airport altitudes up to 10,000 feet. The critical performance envelopes and operational safety limitations for an aircraft established by these tests are directly dependent upon the installed engine and particularly the rated horsepower it provides. The FAA Type Certificate for an airplane or rotorcraft specifies the approved engine installation and identifies the fuel grade or specification as a limitation which constitutes approval of the fuel for that particular make and model of aircraft.

In addition, FAR parts 33, 23 and 27 require materials compatibility testing to substantiate that the fuel is compatible with all engine and aircraft materials to ensure that there are no safety and airworthiness impacts upon components and parts such as pistons, valves, turbochargers, carburetors, pumps, hoses, gaskets, seals, fuel tanks, structure, sealants etc.

Each new make and model of engine and aircraft introduced into the fleet was specifically designed, tested and FAA certificated with 100LL (or equivalent ASTM D910 leaded avgas). Aviation fuel has a direct and significant impact upon both the engine and aircraft performance and compliance with the applicable FAA safety standards. Therefore, the range of safety considerations for a viable unleaded fuel to replace 100LL is a much greater challenge due to the broad range of in-use engines and aircraft that have already been certified. An alternative fuel that has any difference in physical, chemical or performance properties from 100LL raises potentially significant safety implications that will have to be carefully evaluated with respect to both the engine and aircraft. The FAA Advisory Circular AC 20-24 describes the procedures for approving the qualification of new fuels for in-use certificated aircraft engines. It essentially requires re-certification through the same engine tests and inspections discussed above for those airworthiness and performance requirements affected by fuel properties that are different from the existing 100LL.

### C. Other Considerations Related to an Unleaded Avgas Replacement

Although safety is paramount, there are many other considerations for a viable unleaded avgas replacement for 100LL. We must ensure that an unleaded avgas is more environmentally acceptable than the fuel it is intended to replace and does not introduce any new environmental concerns today or in the foreseeable future. As discussed in Appendix C, some of the most promising early research for unleaded avgas centered on the use of ethers such as ETBE, MTBE and TAME as octane enhancers to replace lead. These chemicals were being widely used at the time in automotive gasoline but have been all but banned from use in the U.S. due to concerns about ground water contamination and other reported health issues. Aircraft emissions must also be environmentally acceptable so due consideration needs to be made regarding $CO_2$, NOx, VOCs, carcinogens, and any other potential areas of interest. In addition, consideration of potential human health impact of unleaded avgas will need to be made regarding matters such as handling, storage, venting, toxicity and water solubility.

Another key consideration for a viable unleaded avgas replacement for 100LL is the economic impact. This includes both the upfront costs to transition to an unleaded avgas as well as the long term cost impact of operating on a new fuel. The EPA recognizes in the ANPR that converting in-use aircraft/engines to operate on unleaded aviation gasoline would be a significant logistical challenge, and in some cases, a technical challenge as well. As discussed previously, a change to the approved avgas or modifications to engines and aircraft require FAA certification to ensure compliance with applicable airworthiness safety standards necessary for safety. The FAA certification process is comprehensive and requires significant investment of resources, expertise and time to complete. The cost and resource impact upon both industry and government can be extremely significant depending upon the level of effort and number of modifications that may be necessary to support a transition of the in-use fleet to an unleaded avgas. However, the closer the physical and performance properties of an unleaded avgas to 100LL, the less upfront economic impact there would be, particularly with respect to octane rating since it is a critical fuel property for aircraft engines to maintain rated horsepower which is critical for high performance aircraft to maintain their operational safety limitations. Another potentially significant upfront cost for an unleaded avgas is the impact upon the fuel production and distribution infrastructure and level of modifications/investment that may be necessary. Long-term economic impacts that should be considered are the cost of unleaded avgas per gallon and any potential impact on aircraft/engine operating and maintenance costs. These are ongoing costs incurred by entire in-use fleet for the foreseeable future.

An unleaded avgas that works in aircraft is not a viable replacement for 100LL if it poses environmental and health concerns; would not be produced and made available where and when needed; or imposes significant economic impact that threatens the long-term viability or sustainability of general aviation in the U.S. Due to the relatively small size of the avgas market and the need for a dedicated distribution system for safety controls, the Coalition believes there can only be one avgas and that any future unleaded replacement must accommodate the entire fleet. Additional information on the challenges presented by a dual-fuel approach are discussed in Appendix E.

# APPENDIX C

## Historic and Current Efforts to Reduce Lead in Avgas

### A. Development of The Current 100LL Standard

Lead in aviation gasoline has been an environmental concern since the passage of the CAA in 1970. As a result, industry voluntarily began an initiative to reduce the amount of lead in avgas during the 1970's. After extensive research, it was determined that the fuel specification could be altered to reduce the maximum amount of TEL from 4.24 grams of tetra-ethyl lead per gallon to 2.12 grams without significantly affecting the safety of the current fleet of aircraft. This effort reduced the lead content of avgas by half and resulted in the 100LL standard in use today.

The safety of aviation products is strongly influenced by the design margins established for that product. FAA regulations require that aviation products are certified to standards which ensure the required levels of flight safety. For example, the majority of the reciprocating engine models which power the current general aviation fleet were certified to FAA standards which required that the lean limit fuel flow be 12 percent greater than the leanest fuel flow resulting in detonation. All engineering parameters of an aircraft have safety margins built in so, although the overall safety of the fleet was not affected by the reduction in lead content, the lead reduction did diminish the anti-detonation margin of safety in piston powered aircraft.

The reduction of lead also set off a series of safety and durability problems due to the reduction in lubricating qualities that lead provides in engines. In the years following the switch to 100LL, several aircraft have experienced materials compatibility issues such as fuel leakages due to deterioration of seals in the fuel system. Additionally many aircraft experienced valve seat issues due to the reduction of lubrication delivered by the lead. Valve seats often end up being cracked or worn due to thermal stress, thermal shock or mechanical stress. Lead in avgas adds protection against such stresses.

### B. Research into Unleaded Avgas Alternatives

Twenty years ago, Congress enacted the 1990 CAA amendments. This action—combined with a series of market forces involving the production, handling, and storage of leaded fuels—produced significant concern about the future availability of high-octane aviation gasoline. The most serious issue at the time was the perceived requirement to develop a suitable unleaded replacement for leaded 100LL aviation gasoline that would satisfy the needs of the existing fleet of piston powered aircraft. This effort would involve laboratory research, materials compatibility testing, test cell and flight testing, standards writing, and possible recertification of some or all of the existing fleet of piston powered aircraft. No wholesale technological change of this magnitude had ever been attempted in civil aviation history. In addition, there was significant question at the time whether the petroleum and aviation industries had the necessary resources or financial incentive to invest in this undertaking, particularly the recertification of an aging existing fleet of general aviation aircraft. Still, the general aviation industry reached a consensus in the early 1990's that research should be conducted, employing all possible resources, to find a drop-in unleaded alternative to 100LL.

1. The ASTM International Process

ASTM International, originally known as the American Society for Testing and Materials ("ASTM"), was formed over a century ago and is one of the largest voluntary standards development organizations in the world and a trusted source for technical standards for materials, products, systems, and services. Known for their high technical quality and market relevancy, ASTM International standards have an important role in the information infrastructure that guides design, manufacturing and trade in the global economy. The ASTM committee that oversees the standards for aviation fuels is a consensus-driven member committee made up of stakeholders that have a material interest in aviation fuel such as oil companies, additive producers, original equipment manufacturers ("OEM"), STC providers, and any other concerned participants. The initial work to identify an unleaded aviation fuel began through the ASTM, where the standards for aviation fuels are developed and maintained, in early 1990s.

After a great deal of work there it became evident that the ASTM process, while ideal for the development and maintenance of standards, was not intended or suited for coordinating wholesale research programs. With this in mind, the aviation and petroleum industries submitted a request to the CRC to take on the program of developing an unleaded high-octane aviation gasoline to replace 100LL. In the meantime, work continued at ASTM on specific technical questions concerning the criticality of certain fuel specification limits and qualities. The two programs were populated by many of the same professionals from the aviation and petroleum industries and were closely coordinated to support one another.

2. The Coordinating Research Council process

The CRC is a non-profit organization that directs, through committee action, engineering and environmental studies on the interaction between automotive/other mobility equipment and petroleum products. The formal objective of CRC is to encourage and promote the arts and sciences by directing scientific cooperative research to develop the best possible combinations of fuels, lubricants, and the equipment in which they are used, and to afford a means of cooperation with the government on matters of national or international interest within this field.

A panel was formed under the sponsorship of the CRC with the objective of developing a method to consistently rate aircraft engine octane requirement under harsh repeatable conditions and to determine the general aviation fleet octane requirements. In order to accomplish this objective, the Octane Rating Group had to develop two ASTM standard practices, or methods, to consistently rate aircraft engine octane requirements under harsh, repeatable conditions representative of the operational environment. These methods were used to determine the unleaded fuel octane requirement of the general aviation fleet.

Considering the research and testing required to identify a drop-in fuel, the Unleaded Aviation Gasoline Development Panel was organized under the sponsorship of the CRC and was formed with the objective of conducting research and testing that would facilitate development of the next generation aviation gasoline – a high octane unleaded aviation gasoline as an environmentally compatible, cost effective replacement for the current ASTM D910 100LL fuel. This panel acted as a steering committee, providing oversight and direction for research and testing and supported an interactive, collaborative process with the goal of the development of an aviation gasoline that would meet the requirements of both the existing and future general aviation fleet. Safety, reliable operation, and environmental awareness were the driving principles. Membership of the CRC Unleaded AVGAS Development Panel currently consists of over 60 individuals representing over 40 different organizations and includes representatives from the airframe manufacturers, engine manufacturers, fuel producers, FAA, AOPA, EAA, GAMA, and other interested parties.

Recognizing the large size of the CRC Unleaded AVGAS Development Group and its diverse membership, methods were evolved to facilitate progress. Formation of small Task Groups working as a subset of the CRC Development Group, use of a single lab for blending and analysis, and allocation of the FAA Technical Center engine test facility as the primary test resource were significant factors in achieving this goal. Parallel test programs at the FAA Technical Center and at Cessna Aircraft using different engines to test 30 unleaded blends further enhanced the research process and methods. These factors contributed to facilitating progress of the collaborative effort wherein Task Group members provided base fuels, blend components, and technical guidance with actual engine testing performed by the FAA Technical Center.

3. Challenges Discovered During the Coordinating Research Council Process

From a technical standpoint, the process of identifying an unleaded avgas proved to be far more daunting than any imagined in 1990. To date no unleaded formulation has been found that can meet the octane needs of the existing fleet of high-performance aircraft engines while also maintaining the other necessary safety qualities of an aviation gasoline such as vapor pressure, hot and cold starting capabilities, material compatibility, water separation, corrosiveness, storage stability, freeze point, toxicity and a host of other necessary traits.

Some of the most promising early research centered on the use of ethers such as ETBE, MTBE and TAME as octane enhancers. These chemicals were being widely used at the time in automotive gasoline as oxygenates for environmental reasons. While there was some promising work in this area in raising octane, the goal of 100 motor octane was never reached and efforts in this area have proved largely fruitless because ethers have been all but banned from use in the United States due to concerns raised over ground water contamination and other reported health issues. Other areas of research have focused on the development of super-alkylates as the base stock for aviation gasoline and the use of amines and metal compounds other than lead as possible additives. So far, none has provided a satisfactory solution.

As literally hundreds of unleaded fuel blends were proposed and tested some fundamental questions began to emerge about the qualities of leaded versus unleaded fuels such as whether an unleaded gasoline of a given octane rating would perform in an aircraft engine in an equivalent manner to a leaded gasoline of the same octane rating. While it would seem that the experience of the transition from leaded to unleaded automotive gasoline would have covered this ground, fundamental question such as this had never been answered or the results quantified. In the end the answer was a definitive and surprising no. Leaded and unleaded fuels of the same octane rating do not provide the same level of anti-knock and detonation protection. This is but one example among many of the complex work that has been necessary to provide a technical understanding of the problem and a foundation on which a solution can be based. These are not academic exercises for the sake of knowledge but rather critical data in support of flight safety.

Other areas of research have been focused on the fleet of aircraft engines themselves. Historically, all of the piston aircraft engines in the world have been developed, tested and certificated to work on a fuel of known qualities and octane rating. Once shown to work with a margin of safety using the fuel available and largely unchanged since the 1940's the certification process was complete from a fuel standpoint. No one has ever made any attempt to determine the actual octane needs of the piston engine fleet and such a determination was unnecessary as long as the engines worked on the 100 octane fuel that has been available. For the first time, significant laboratory controlled testing of aircraft engines was required to determine the actual octane needs of the piston engine fleet in order to answer the question of how low octane could be dropped before the safety margin against destructive detonation would be compromised or eliminated entirely. As one would expect the answers varied with each make and model of engine, but in many instances every bit of the anti-detonation characteristics of the 100LL was required in order to safely operate the engine. This lead to the conclusion that for a percentage of the fleet, any reduction in octane would have a serious impact on the safety and utility of the aircraft.

4. Coordinating Research Council Research Results

In June 2010, the CRC submitted their final report on the research results on "Unleaded, High-Octane Aviation Gasoline." In excess of 279 experimental unleaded high octane blends were formulated and tested by the CRC UL AVGAS Development Group. After all of the research and testing the UL Development Panel did not identify a transparent replacement for the 100LL AVGAS product however there were significant "lessons learned." Among those lessons learned were:

- Although full scale engine tests indicated some blends were capable of providing knock free operation in the test engine, these blends represented the use of specialty chemicals which may require further evaluation with respect to environmental impact.

- Although some experimental blends of specialized components were shown to exceed the 100LL specification of 99.6 MON minimum, such formulations are very different as compared to the current ASTM D 910 product and potentially compromise other important fuel properties and specifications.

- Leaded and unleaded Avgas of the same octane number do not perform the same in engines - Leaded avgas offers greater octane satisfaction in full size engines when compared to unleaded products of similar laboratory MON.

- Test results indicated a minimum unleaded octane requirement greater than 100 MON is needed for naturally aspirated engines and higher for turbocharged engines depending upon engine power output and configuration.

### C. Ongoing and Future Efforts to Reduce Lead in Avgas

The CRC is continuing efforts to develop an unleaded alternative to 100LL and has established a new research initiative to evaluate the current D910 specification to determine what properties, other than octane, can be expanded without compromising safety. The avgas specification defines several physical and performance properties, all important to aircraft/engine safety and performance, which is why unleaded avgas research conducted to date focused on the development of a drop-in replacement for 100LL that matched all the properties. However, a drop-in replacement has not been identified so determining the ability to expand avgas properties other than octane provides greater opportunities for the development of a high-octane unleaded avgas. The CRC has begun research to determine the critical safety values of all of the performance specification parameters to identify areas of flexibility.

The CRC has also established a new task group to evaluate reducing the amount of lead in avgas while maintaining all other properties to determine whether a near-term reduction in lead emissions from general aviation is possible. The data analysis and drafting of the reports are currently being finalized, but initial findings indicate the acceptability of a 20 percent reduction in lead content. If the findings in the final report are consistent, it will be used as the basis for a ballot proposing a change to the D910 specification to reduce maximum TEL content for 100LL by 20 percent for consideration at the ASTM December 8, 2010 meeting.

The FAA is also continuing its efforts to reduce or eliminate lead emissions from general aviation. In collaboration with the general aviation community, the FAA has committed to test, adopt, and certify a new aviation gasoline fuel standard as set forth in the 2009-2013 Flight Plan. To further this effort, the President's FY 2011 budget submission not only reinstates, but proposes to significantly increase funding for unleaded avgas research efforts and the AFETF.

The FAA RE&D budget includes a new research program item A11.m for "NextGen – Alternative Fuels for General Aviation" with $2 million annually for five years. Activities include assessment of very-low-lead avgas and potential high-octane unleaded fuels along with development of the test and evaluation methods necessary to support certification approvals for the existing fleet to transition to a future unleaded avgas. The FAA states that the primary goal of this research is the elimination of lead emissions from piston powered aircraft. Various alternatives to achieve this goal will be explored, including:

- Investigation of unleaded replacement alternatives to current leaded avgas (100LL) used in piston engines. To the greatest extent possible the replacement alternative(s) should be equivalent in performance to 100LL and be a seamless, transparent change to a general aviation pilot.

- Technologies for modification of piston engines to enable their safe operation using unleaded fuel.

- Qualification and certification methodologies for alternative fuel safety performance.

- Investigation of fleet lead emissions which will support evaluation of various approaches to for achieving emissions reductions.

Congress has also recognized the importance and supported moving forward with unleaded avgas initiatives. The House Transportation/Housing and Urban Development Appropriations Bill, FY 2011 fully funds the FAA's new initiative to research and test new unleaded fuels and piston engine modifications to seek a safe alternative to the currently utilized leaded avgas. The Committee report accompanying the Bill states that:

> "The Committee recognizes the need for FAA to implement a program to develop aircraft engine emissions and airworthiness regulatory standards and policies to remove lead from the fuel used in piston engine aircraft. This program should be coordinated with current industry initiatives established to transition the piston engine aircraft fleet to reduced lead or unleaded fuel. The FAA should collaborate in this effort with industry groups representing aviation consumers, manufacturers, fuel producers and distributors, EPA and other relevant agencies as appropriate. FAA should also take proper account of aviation safety, environmental improvements, technical feasibility and economic impact on the current and future general aviation fleet. The Committee recognizes that this program will have a resource impact on the FAA and expects FAA to detail in future budgets the resources necessary to implement this program including certification."

## APPENDIX D

### FUTURE CONSIDERATIONS REGARDING AIRCRAFT ENGINE EMISSIONS STANDARDS

In addition to describing and inviting comment on the current data to support the EPA's endangerment and cause or contribute finding, the ANPR also describes considerations regarding emission engine standards and requests comment on approaches for transitioning the piston-engine fleet to unleaded avgas. This Appendix provides additional information and recommendations from the Coalition regarding possible future rulemaking by the EPA and the FAA.

The aviation and petroleum industries have been working together to tackle the technological barrier of producing an unleaded aviation gasoline that mirrors the performance and property characteristics of 100LL. Thus far, no "drop in" unleaded solution has been identified to replace 100LL. The EPA recognizes this in the ANPR when stating that transitioning in-use aircraft/engines to operate on unleaded aviation gasoline would be a significant logistical and technical challenge and would likely require FAA safety certification. It is clear that compromises will have to be made and the challenge is to identify where those compromises can be made with the least impact on safety, cost, availability and aircraft performance.

### A. Assessment of Reduced Lead Avgas for Near-Term Reductions in Lead Emissions

A technical and regulatory process to develop and implement a transition to an unleaded avgas that adequately considers aviation safety, technical feasibility and economic impact will require several years. Therefore, the aviation and petroleum industries have been assessing the feasibility of replacing 100LL with a "very-low-lead" formulation in order to provide near-term reductions in lead emissions inventory from general aviation which could be implemented in time to support National Ambient Air Quality Standards for Lead compliance activities. The CRC has established a new task group to evaluate reducing the amount of lead in avgas while maintaining all other properties necessary for a "drop in" replacement to determine whether a near-term reduction in lead emissions from general aviation is possible. The data analysis and drafting of the reports are currently being finalized, but initial findings indicate the potential of a 20% reduction in lead content. If the findings in the final report are consistent, it will be used as the basis for a ballot proposing a change to the D910 specification to provide for a 100 octane very low lead avgas with a 20 percent reduction in the maximum TEL content from today's 100LL. This ballot is expected to be considered at the ASTM December 8, 2010 meeting.

### B. Program to Facilitate Unleaded Avgas Replacement for 100LL

The Coalition is working with the FAA to develop and implement a comprehensive program to facilitate the qualification of an unleaded avgas replacement for 100LL and safe transition of the in-use fleet. We believe that FAA's role is critical in this effort given that the FAA has the statutory authority and sole responsibility for implementing standards for aircraft including the approval of an unleaded avgas and safety certification of engines and aircraft that use it. This program should be coordinated with current industry initiatives and collaborate with industry groups representing aviation consumers, manufacturers, fuel producers and distributors, the EPA and other relevant agencies as appropriate. This program should work first and foremost to ensure aviation safety and to take proper account of technical feasibility, environmental improvements, economic impact on the current and future general aviation fleet, as well as fuel production and distribution, to ensure the sustainability and growth of general aviation.

### C. Consideration of Approaches for Transitioning the Fleet to Unleaded Avgas

A clearly defined transition plan from 100LL to a replacement unleaded avgas is necessary to provide a common timeline to all stakeholders including manufacturers, operators, FAA, EPA, NGOs, etc. A transition plan with appropriate timeframes will also foster the appropriate level of investment and R&D necessary to ensure the continued safety and viability of general aviation. However, a viable unleaded avgas replacement for 100LL must first be identified in order to consider the following elements of a transition plan: availability of FAA approval and certification policy and resources to enable the transition, new production engine and aircraft cut-in to be able to operate on unleaded avgas, the development and availability of modifications to transition existing aircraft, and unleaded avgas production and distribution. Another important consideration that will have a significant impact upon the transition and measures necessary to ensure safety is the ability for 100LL and the unleaded avgas to comingle in both the distribution infrastructure and in aircraft operation. Transitioning newly-manufactured and in-use aircraft to be able to operate on unleaded avgas by some future date will require that they be able to operate on both 100LL and unleaded avgas, or a blend thereof, until the avgas available at airports across the country also transitions.

However, the overall approach for transitioning the fleet to an unleaded avgas depends upon whether the existing 100LL leaded fuel could be phased down over time as an unleaded avgas is introduced (dual-fuel transition used for automotive gasoline) or if the transition from a 100LL to an unleaded avgas would need to happen all at once. The EPA recognizes the significant challenges for supply, distribution and storage of avgas since annual demand is very small in comparison to motor gasoline yet its use is as geographically widespread. Appendix E provides detailed information regarding the challenges of a dual-fuel approach. The stark differences between aviation gasoline (avgas) and automotive gasoline usage and distribution make a dual-fuel transition approach impossible.

# APPENDIX E

## CHALLENGES OF A DUAL FUEL TRANSITION APPROACH

On January 10, 1973, the EPA required that unleaded fuel for automotive uses be made available by mid-year 1974. This requirement began a process that ended in 1996 when the EPA finalized rules for a complete ban on the use of lead in automotive fuels. The 1973 requirement created a dual availability of leaded and unleaded automotive fuel, a strategy that has been suggested as a solution to reduce the amount of lead used in general aviation. Stark differences between aviation gasoline and automotive gasoline usage and distribution, however, make this strategy impossible.

While the introduction of additional grades of fuel was a sound strategy for the reduction of lead use in the automotive industry, there are serious challenges to and concerns with the application of that strategy to aviation. Increased costs, lowered availability and decreased safety combine to make a dual fuel solution, or transitional solution, to the issue of lead use in aviation unworkable.

The challenges facing the production, transportation and distribution of aviation gasoline in a dual fuel environment was summarized in the Aviation Gasoline Survey – Summary Report released in June of this year by API:

> "A key result from the survey indicated that no company [current avgas producer] would provide both 100LL and an unleaded avgas at the same time. The survey asked what infrastructure issues might become a problem in selling a dual fuel (that is, 100LL and unleaded avgas). All of the respondents indicated problems in maintaining duplicate distribution systems during the phase in, having to add new tanks to handle two fuels and cross contamination issues."

The first point that must be noted when understanding the impossibility of a dual fuel solution for aviation is the very low volume of avgas produced, and therefore used, in comparison to overall transportation fuel. According to the U.S. Energy Information Administration, avgas production accounts for only 0.1 percent of overall transportation fuel production.

### A. Production, Transportation and Distribution

In most cases, avgas is currently delivered to distribution terminals from manufacturers then shipped via over-the-road trailer to on-airport fuel service providers. Significant difficulties exist today, in a single-grade avgas environment, in finding space for avgas storage at delivery terminals. Fuel storage capacity at terminals is limited and due to the very specific quality requirements of aviation fuels, as opposed to automotive and other fuels, dedicated tankage is required, meaning terminals must make a business decision as to whether to supply avgas. Many terminals, due to the very low throughput of avgas, in comparison to other products, have chosen not to supply avgas at all. The limited number of terminals that do supply avgas are serving an ever-increasing area, leading to increasing shipping costs to the final user.

The existing challenges of avgas distribution would be exacerbated by the introduction of a second grade of avgas as the current throughput is split into two distinct products. The limited tankage available at supply terminals would become more problematic as terminals would be required to segregate leaded and unleaded avgas. Terminals would be required to evaluate their existing storage availability, apply the lowered throughput per tank, and make a determination if a business case exists to supply avgas. Some terminals would be expected to exit the supply chain while some may, due to limited storage availability, choose to supply only one of the available grades. Terminals that chose to continue to supply avgas, either one or both grades, would see reduced revenue per storage tank due to the reduced throughput per tank, leading to possible higher storage and delivery rates for downstream customers.

Over-the-road trucking companies that handle delivery of avgas from supply terminals to airport facilities would also be affected in a dual grade avgas environment. Due to the strict segregation requirements for aviation fuels, tanker trailers would need to be avgas grade dedicated or trailers would need to be steam cleaned every time a grade change occurred. The cost of additional tanker trailer dedication or ongoing steam cleaning would add even more cost to the delivery of avgas.

**B. On-Airport Fuel Service Providers**

In a dual grade avgas environment, on-airport fuel service providers, known as fixed base operators (“FBOs”), would experience significant negative effects in addition to the possible higher cost from supply terminals. FBOs currently have storage capabilities for one grade of avgas and would be required, due to the need to segregate different grades of aviation fuel, to construct or purchase additional infrastructure to handle additional grades. This additional infrastructure would include storage tanks, filtration systems and associated piping and fuel delivery vehicles. Many existing airport or FBO storage facilities have been designed for current needs and would not have room for additional storage tanks. These facilities would need to be completely redesigned or separate facilities for the new grade of avgas would need to be built.

In addition to infrastructure costs, FBOs would also face additional manpower costs. Unlike its automotive counterparts, aviation fuel and the equipment used to store and handle it must undergo a continuous regimen of quality control testing and inspection. Each storage tank, or fuel delivery vehicle, must undergo specific daily, monthly, quarterly and annual inspection to maintain compliance with industry standards. A single tank or fuel delivery vehicle can require up to 214 man-hours or more per year to maintain quality standards.

Faced with a dual grade avgas environment, FBOs would be forced to make a business decision as to whether to supply both grades or only one of the two possible grades. The low overall volume of avgas throughput combined with the higher per gallon manpower cost for into plane delivery (an individual avgas fuel sale tends to be a factor of 10 or more, in gallons, less than that of jet fuel) would likely lead to many FBOs choosing to supply only one of the possible grades of avgas. Further complicating the decision would be the long-term strategy relating to dual grade use. If the introduction of a second grade of avgas is envisioned to be a transition strategy, as it was in the automotive world, FBOs would be forced to amortize the cost of the additional infrastructure over a far shorter period of time than most other large scale capital investments.

While it is expected that many FBOs would choose not to carry additional grades of avgas, some would more than likely not have a choice. The airport sponsor (owner) could require, through amended minimum standards or other mechanisms, that FBOs supply both grades of avgas to ensure that the airport attracts a wide class of users. FBOs at these airports would be required to carry both grades regardless of whether it is profitable to do so.

FBOs carrying both grades of avgas would experience significant changes in inventory management as their overall avgas throughput is split between two distinct products. The delivery of avgas by tanker trailer severely limits the ability of FBOs to modify shipping amounts. FBOs choosing to receive avgas in smaller quantities would still pay the same shipping charge as a full load. The end result is either that avgas at FBOs would spend more time in storage, tying up more capital in inventory, or the FBO would accept smaller quantities of avgas, incurring increased shipping and delivery costs.

### C. Safety and Operational Considerations

The introduction of multiple grades of avgas also presents significant operational and safety issues. As airports, supply terminals and FBOs make business decisions as to whether to carry both grades of fuels, the result could likely be reduced availability of certain grades of avgas at specific airports. This patchwork of fuel availability stands to impose significant burdens on aircraft operators, as those operators eliminate from use airports not carrying the correct grade of fuel.

From an FBO perspective, a leading safety concern is misfueling. Misfueling refers to the delivery of the incorrect grade of fuel, or incorrect quantity, to an aircraft. Misfueling is a serious safety concern and has led to aircraft accidents in the past. The industry has worked hard to eliminate misfueling through the use of selective spouts and aircraft filler ports to segregate avgas and jet fuel. The introduction of a second grade of avgas would reintroduce the serious dangers of misfueling. Aircraft requiring lead could be subject to serious engine damage or failure in the event that the aircraft was inadvertently fueled with unleaded avgas and/or lower octane avgas.