A PRIVATE-FEDERAL COLLABORATIVE MODEL: THE NATIONAL ALTERNATIVE FUELS LABORATORY PROGRAM

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INTRODUCTION

The U.S. Department of Agriculture (USDA) -sponsored National Alternative Fuels Laboratory (NAFL) program at the University of North Dakota Energy & Environmental Research Center (EERC) was initiated to help build partnerships for demonstration and commercialization of alternative fuels. Approximately half of the NAFL annual budget is set aside for use in cost-share projects with nonfederal partners and advertised as the NAFL Request for Collaborative Proposals, which is published in ethanol industry newsletters and on the EERC Internet site. Successful proposals require 50% cost share and 90% of project labor performed at EERC. Descriptions of selected NAFL-initiated partnerships and projects are provided below.

AN ETHANOL-BASED ALTERNATIVE TO 100LL AVIATION FUEL

A team comprising EERC, South Dakota State University at Brookings (SDSU), Great Planes Fuel Development in Brookings, Lake Area Technical Institute at Watertown, South Dakota (LATI), the South Dakota Corn Marketing Board, and Texas Skyways, San Antonio, has developed and is pursuing commercialization of an economically competitive ethanol-based alternative to lead-containing aviation gasoline. Unlike essentially all commercial automobile fuel sold in the United States today, commercial 100-octane aviation fuel for piston engine aircraft (known as "avgas" or "100LL") still contains lead, which is a human health hazard. Replacing avgas with an ethanol-based aviation fuel will improve the environment (since the high octane rating of ethanol eliminates the need for lead) and reduce foreign oil dependency. Ethanol is also cheaper than avgas. Current ethanol and avgas prices are about $1.50 and $2.25 per gallon, respectively. An optimized blend of ethanol and a suitable petroleum-derived additive (to supply needed volatility and serve as a denaturant) can provide better engine performance and higher fuel efficiency than avgas by enabling the use of a higher engine compression ratio. An optimized ethanol blend will also enable better engine starting at lower temperatures than achievable with 98% (denatured) ethanol, because of an increase in Reid vapor pressure (Rvp) from about 2.3 pounds per square inch (psi) for 98% ethanol to about 7 psi for a blend of 80% to 85% ethanol with an appropriate additive.

Fuel formulations prepared using nondenatured ethanol and a high-octane petroleum blendstock from a major U.S. oil company were evaluated in the lab at EERC. Following optimization of a fuel comprising about 85% nondenatured ethanol and 15% petroleum blendstock–biodiesel mixture (biodiesel was added to provide lubrication), U.S. Bureau of Alcohol, Tobacco, and Firearms approval of the selected petroleum blendstock as an ethanol denaturant was requested and granted. GPFD successfully applied for Federal Aviation Administration (FAA) approval to flight-test two engine–airframe combinations with aviation-grade E85 (AGE85), and initiated on-ground engine testing and flight testing for FAA certification. As part of the certification process, EERC prepared a preliminary fuel specification for FAA review. Currently, GPFD is working with Texas Skyways to obtain FAA certification of three engine–airframe combinations for use with AGE85. In preliminary flight tests conducted with a Continental O-470-U/TS (that underwent minor carburetor modifications for use with AGE85 but no engine modifications), AGE85 and 100LL were shown to be essentially equal in performance, but the AGE85 provided significantly higher fuel energy utilization efficiency. Fuel utilization data acquired demonstrated that range is not simply a function of fuel energy content (about 88,200 and 120,000 Btu/gallon for AGE85 and 100LL, respectively), but also a function of how the energy is used. Because of its higher latent heat of vaporization than 100LL (and possibly, other factors), ethanol combustion produces less waste heat, which means that a greater portion of its energy goes toward moving a plane than compared to 100LL. This may be the primary reason why the AGE85 range reduction is only about 10 to 15% versus 100LL, instead of the 27% that would be predicted based on the energy content difference between the two fuels and the assumption that the fuels will combust with equal thermodynamic efficiency. Fuel efficiency data for ethanol-based fuels versus petroleum fuels (with both aircraft and automobiles) need to be determined under lean-burn conditions that take advantage of ethanol's capability to provide engine-safe power and performance at higher air-to-fuel ratios than gasoline, especially under cruise conditions. Flight tests are ongoing, and oil company commitment is being sought to produce and distribute AGE85 or provide AGE85 petroleum blendstock for blending and distribution by another entity. Current effort is focused on companies with midwest oil production capability to enable use of regionally produced ethanol. Because of increasing U.S. EPA pressure that has resulted in the prohibition of avgas in pipelines and the need for shipment by truck, avgas producers are aware of the urgent need to develop unleaded avgas alternatives.

OFF-SITE REGENERATION OF ETHANOL DEHYDRATION MOLECULAR SIEVES

Molecular sieves (mol sieves) are used for dehydration at numerous ethanol production facilities and oil and gas refinery operations throughout the United States. In the ethanol industry, mol sieves adsorb water from 95% pure ethanol and yield 100% (200 proof) product, and sieve regeneration (dewatering) is performed on-site by applying a vacuum to the "bottles" in which the sieves are contained. In the event of a process upset or other unplanned occurrence, mol sieves can become contaminated and undergo a reduction in effectiveness, which may result in reduced product output. Remediation of reduced output requires either sieve replacement or off-site regeneration to remove the offending contamination. Off-site regeneration of mol sieves is common in the oil and gas industries and is normally achievable with thermal treatment under a specific atmosphere. Temperature and atmospheric requirements depend on type and extent of contamination.

Because of its demonstrated economic viability in the oil and gas industries, an EERC partnership with CRI International, a full-service catalyst management company, was initiated to pursue commercialization of off-site mol sieve regeneration for the ethanol industry. Normally, the price of off-site regeneration ranges from one half to two thirds the cost of new sieves. Factors affecting cost include treatment required (based on type of contamination, which can include carbohydrates and their polymerization products, sulfites, and lubricant entering the process stream due to a system upset), transportation, and amount of material requiring regeneration. Figure 1 compares the performance of contaminated mol sieves from a midwest ethanol plant to the performance of off-site regenerated sieves from the same plant. The figure demonstrates the technical feasibility of the process. Currently, EERC and CRI International are evaluating process economics with contaminated sieves from another producer.

FLEX-FUEL VEHICLE FUEL ECONOMY TESTING

Based on preliminary fuel economy data acquired during the above-described ethanol-based aviation fuel development effort, EERC initiated fuel economy testing with E85 automobiles. Initial results indicate highway and city driving mileage reductions of about 28%, which are consistent with industry-reported mileage and mileage calculated based on energy content per gallon versus gasoline and assuming gasoline thermodynamic efficiency. However, the E85 1997 flex-fuel Ford Taurus cars used for the tests are programmed to operate at stoichiometric fuel combustion conditions. While there are several reasons for avoiding "lean-of-stoichiometric" combustion of gasoline, including increased NO_x emissions and increased potential for valve damage, there are indications that leaner ethanol combustion may not produce the same negative effects (1-3). Current flex-fuel vehicle work is focused on adjusting fuel flow to achieve lean-of-stoichiometric combustion and monitoring emissions of NO_x, CO, CO_2, O_2, and total hydrocarbons in on-the-road tests with a vehicle-mounted infrared gas analyzer.

GASOLINE SURVEYING TO MONITOR COMMERCIAL FUEL COMPOSITION & PROPERTIES

To meet objectives of the 1990 Clean Air Act Amendments and help ensure against unsafe levels of tropospheric carbon monoxide and ozone, many regions around the U.S. have implemented reformulated gasoline (RFG) or oxygenated gasoline (oxyfuel) programs. Programs that rely extensively on ethanol to meet fuel oxygen requirements are in a unique position to ensure and accelerate marketplace acceptance of ethanol as a high-octane blendstock for the U.S. gasoline pool. Success in these programs is crucial to the ethanol industry and requires that base gasolines used in ethanol blends meet health, environmental, and performance standards to ensure a positive relationship between ethanol and public health, air quality, and engine performance. Through the NAFL program, the EERC has formed partnerships with ethanol industry groups to perform gasoline surveys in which fuels are sampled (at the pump) and analyzed to provide data and insight on major supplier blending and marketing practices. Data from the surveys can be used to compare commercial fuel parameters to regulated parameters of the U.S. Environmental Protection Agency (EPA) RFG program, the California RFG program, other state gasoline programs, and the EPA Anti-Dumping Requirements for Conventional Gasoline. Table 1 lists EPA Phase 1 RFG typical properties, specifications for California Phase 2 RFG, and annual average parameters for "EPA Statutory Baseline" fuel.

To implement the anti-dumping requirements, EPA worked with gasoline refiners, blenders, and importers to develop individual "baseline fuel" specifications. Each refiner must meet individual baseline fuel requirements developed based on a set of fuel parameters, emissions, and volumes representing the quality and quantity of the refiner's 1990 gasoline. All individual baseline fuel specifications are confidential between EPA and refiners and are not available for public review. Anti-dumping compliance is based on annual average composition and characteristics for gasoline from each regulated refinery, refinery aggregate, importer, or blender. Each refiner reports annual gasoline data to EPA at the end of each production year, and EPA also periodically conducts audits of production, blending, storage, and loading facilities to help ensure that baseline fuel specifications are met. If a refiner does not have an established individual baseline fuel on file with EPA, this refiner is required to meet the specifications of the EPA Statutory Baseline. Demonstration of compliance using the statutory baseline is based on the annual fuel parameter values shown in Table 1. The statutory baseline fuel parameters were developed using 1990 fuel composition data compiled through a nationwide petroleum industry fuel survey. The data provided in the twice-annual industry gasoline surveys (which arc guided by the American Petroleum Institute) are acquired by petroleum companies and supplied to the survey marketer compilation and reporting. All fuel composition data are reported without oil company identification, which prohibits use of the survey to associate a specific fuel with a specific refiner.

An EERC summer 1997 midwest region gasoline survey showed that 27 of 33 midgrade (89 octane) fuels sampled contained ethanol, including 15 of 21 fuels that were not required to contain oxygen, indicating the free-market use of ethanol to provide octane. The survey showed that although two of three major suppliers frequently chose to use ethanol as a viable blending component, one major supplier consistently avoided the use of ethanol except with fuels required to contain oxygen. Figure 2 compares EERC survey fuel data with BDM survey averages for the same region and EPA and California fuel specifications, and Figure 3 is a similar comparison using winter fuel data. The figures show that while both the EERC and BDM survey average fuel compositions meet EPA baseline specifications, one major supplier significantly exceeds (by almost double) the EPA statutory baseline value for olefins in both winter and summer. It is likely that this supplier has an individual baseline on file with EPA, and because this information is proprietary, it is impossible to determine compliance status with currently available information. Additionally, although EPA-specified sampling and analysis procedures were employed, compliance status determination would likely require a more extensive database than assembled for this survey. A key benefit of gasoline surveying is in helping to ensure that ethanol-blended gasolines are clean and perform well, which is crucial to ensuring ethanol's future as an automobile fuel.

ALTERNATIVE FUELS IMPLEMENTATION VIA RED RIVER VALLEY CLEAN CITIES

The Red River Valley Clean Cities (RRVCC) coalition was established to promote and implement regional alternative fuels use by building partnerships to erect alternative fuels infrastructure, procure alternative fuel vehicles (AFVs), and demonstrate beneficial environmental, performance, and economic effects of alternative fuels. The NAFL-led coalition comprises government and industry stakeholders in Canada and the U.S. located in and between Grand Forks–East Grand Forks on the North Dakota–Minnesota border and Winnipeg, Manitoba, Canada. The route between Winnipeg and Grand Forks (Canada Highway 75 and U.S. I29) represents the northern end of the I29–I35 Midcontinent Trade Corridor. The coalition is fuel-neutral, as demonstrated by a stakeholder membership that includes regional ethanol and electricity interests and upper midwest propane and natural gas suppliers. Current RRVCC initiatives include working with the ethanol industry, grower organizations, state agencies, and gasoline retailers to establish commercial high-blend ethanol (E85) stations, working with the University of North Dakota to procure E85 and propane vehicles, establishing a group of natural gas interests, comprising natural gas and fueling equipment providers, state agencies and private fleets, and the U.S. Postal Service, which will construct compressed natural gas fueling sites in thc rcgion.

REFERENCES

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Table 1. Regulatory Fuel Specifications.

	EPA Phase 1 RFG Typical Properties	California Phase 2 RFG Specifications Average Limit	EPA Anti-Dumping Statutory Baseline Fuel Parameters Annual Average
Rvp, psi	7.2 – 15.0	7.0[1]	8.7
T50, °F	202	200	Not reported
T90, °F	316	290	Not reported
Aromatics, vol%	23.4	22.0	28.6
Olefins, vol%	8.2	4.0	10.8
Benzene, vol%	1.0	0.8	1.6
Sulfur, ppm	302	30	338
Oxygen, wt%	2.0	1.8 – minimum[2] 2.7 – maximum[2]	Not required

[1] Absolute maximum limit – no average limit allowed.
[2] Absolute limits for winter gasoline – summer values are 0.0 minimum, 2.7 maximum.

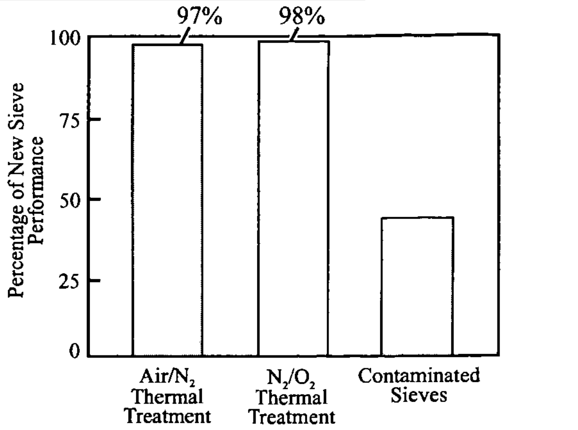

Figure 1. EERC–regenerated mol sieve water uptake performance.

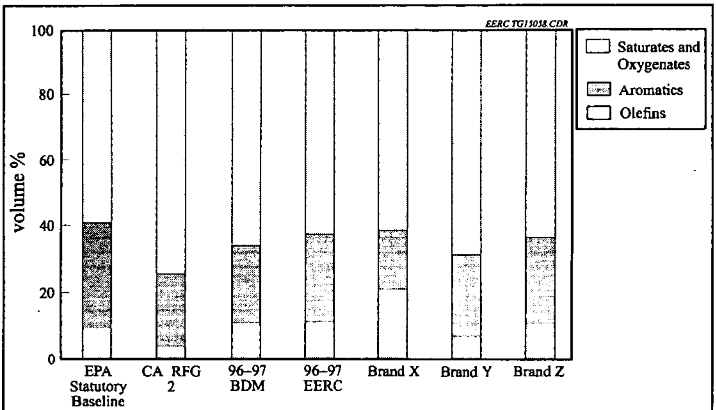

Figure 2. Twin Cities summer 1997 87 octane blends.

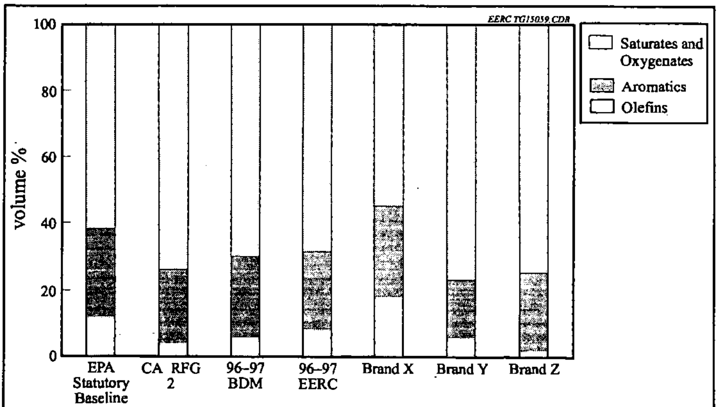

Figure 3. Twin Cities winter 1996-1997 87 octane blends.