Biodiesel Feasibility Study
for the
Miami International Airport
Miami, Florida

Prepared for

Miami-Dade Aviation Department
P.O. Box 592075
Miami, Florida 33159

Prepared by

EA Engineering, Science, and Technology, Inc.
14361 Commerce Way, Suite 103
Miami Lakes, Florida 33016

and

Antares Group, Inc.
4351 Garden City Drive, Suite 301
Landover, Maryland 20785

Date
August 2004
FINAL
13750.12

EXECUTIVE SUMMARY

The Miami-Dade Aviation Department (MDAD) is implementing an airport-wide plan to achieve a 10% reduction in volatile organic compound (VOC) emissions by the year 2010. Several initiatives under this plan will include best management practices and implementation of advanced, more efficient, or alternative fuel technologies. One of these initiatives was the development of an Alternative Fuels Master Plan (AFMP) for Miami International Airport (MIA).

The AFMP recommends a scheduled implementation of alternative fuel technologies across MDAD's airside and landside operations through 2010. This technology implementation was derived based on an analysis of alternative fuels and technology options, current MDAD equipment inventories, and unique MIA operational procedures and parameters. Biodiesel, specifically B20, use was one of the key AFMP elements, especially in medium- and heavy-duty vehicle applications. Biodiesel is a fatty acid methyl (or ethyl) ester-based fuel that can be produced from a variety of natural vegetable oils or recycled yellow grease (waste fryer oil from restaurants). B20 is a blend of 20% pure biodiesel and 80% petroleum diesel and is typically used because it offers a good compromise between issues related to cost, environmental benefits, material compatibility, and temperature stability.

While there is significant potential for biodiesel use in the MDAD diesel equipment inventory, there is a variety of operational and cost issues with biodiesel that need to be addressed prior to wide-scale use of the fuel at the airport. A considerable portion of the MDAD diesel equipment inventory is more than 10 years old and the original fuel system materials used in this generation of equipment were not necessarily compatible with biodiesel. Using biodiesel in this equipment could potentially lead to certain elastomeric and metal material breakdown and subsequent vehicle operational problems over time. In addition, while the AFMP identified significant potential for biodiesel use for MDAD vehicle applications on both the landside and airsides, only limited analysis was performed concerning biodiesel use in airside stationary applications such as stand-by generators and fire pumps. In general, little attention has been given to biodiesel use in stationary power generation applications. Biodiesel offers the same advantages to stationary power applications as vehicle applications in terms of conventional diesel fuel displacement, lower exhaust emissions, improved fuel lubricity characteristics and limited engine modifications. However, long-term biodiesel storage becomes a relevant issue for many of these stationary applications which are not operated frequently, including the MDAD generator and fire pump populations at MIA.

Based on these concerns, this biodiesel feasibility study was commissioned by MDAD to address these issues and provide recommendations for biodiesel implementation. Both high- and low-level biodiesel blends were investigated to assess equipment fuel line material compatibility issues, regional biodiesel product stability and quality, cost-effective power equipment applications, and airport fuel storage requirements and costs. The goal of this study is to provide recommendations for a phased implementation of biodiesel use in MDAD airside equipment over the next five to ten years, consistent with the facility Capital Improvement Plan timeframe, as well as to assess the petroleum fuel savings and VOC reductions associated with this airside implementation. The results also provide back-up analysis and data for the AFMP and its

projected landside biodiesel applications in employee shuttle buses and administrative/security vehicles.

MDAD's current airside diesel vehicle inventory includes 192 pieces of equipment, primarily on-road vehicles and non-road equipment such as stationary generators, baggage tugs, forklifts, tractors and lawnmowers. The majority of the diesel vehicles are more than five years old, and a third of the vehicles are over ten years old. Based on operational data for the current airside diesel equipment categories, MDAD's inventory emits about 11.1 ton/yr of VOCs, 173 ton/yr of carbon monoxide, 35.8 ton/yr of nitrogen oxides, 1.7 ton/yr of particulate matter and 4,420 ton/yr of carbon dioxide. Achieving a 10% reduction in VOC reduction and petroleum fuel use would equate to 1.1 ton/yr of VOC emissions and 60,829 diesel gallon equivalents per year.

VOC emissions reductions for biodiesel depend on the percentage of biodiesel in the blend. For B20 blends, VOC reductions of about 20% can be achieved compared to conventional diesel. In general, fuel system materials used in current diesel vehicles are biodiesel compatible, and thus no additional capital cost is required to use B20. Vehicles older than ten years may have some fuel system materials that require replacement with newer biodiesel compatible prior to B20 use. Results of this study indicated that B20 could be used in 55% of the current MDADairside inventory with little, or no modifications.

Biodiesel does not require a specially designed refueling infrastructure. Existing diesel tanks can easily and cost-effectively be cleaned and fitted with appropriate biodiesel compatible material. The only additional operating costs involve 2-3 fuel filter replacements in the first several months after switching each vehicle to biodiesel and the incremental fuel cost (typically $0.20/gallon for B20). As a result, the increased annual operating costs are low, especially when compared to other alternative fuels.

A staged biodiesel implementation was developed in this study that minimizes the risk with B20 and to have fleet personnel gain operation experience with vehicles likely to have the least problems. Six tiers were developed. The initial implementation tier focused on the largest group of equipment and includes non-critical use roles (police, fire, etc.). It included equipment in which material compatibility is less likely to be problematic, and fuel usage rates were higher to avoid fuel stability issues. Subsequent implementation tiers include older vehicles that may possibly require some fuel system material replacement, vehicles that have longer total fuel storage times, and critical use vehicles. Estimates of the VOC reductions, fuel savings, additional operational and capital cost were developed for each tier. The largest number of equipment implemented was in Tier 1, and thus the reductions are the greatest. Tier 1 VOC reductions of 1.06 tons (96% of the goal), and fuel savings of 59,998 diesel gallon equivalent (DGE) (124% of the goal) were estimated. Implementing all six tiers would result in a 1.1 ton VOC reduction (100% of the goal) and a 95,015 DGE (197% of the goal).

Based on the six implementation tiers for biodiesel introduction into the MDAD airside equipment inventory, it is recommended that Tiers 1 and 3 be given greater initial consideration. These tiers provide significant VOC emission reductions and fuel savings over the period of year 2004 to 2010, and combined, result in cost-effective means of achieving MDAD's 2010 goals for VOC and petroleum fuel reductions at the airport. Tier 1 would start implementation as planned in year 2004 and proceed through year 2010. This includes the newer vehicles in the inventory with higher fuel use. Over the course of years 2004 and 2005, it is recommended that MDAD take fuel samples on a monthly basis to ascertain how stable the regional biodiesel supply is and how well the fuel holds up to long-term storage. Assuming the fuel quality results and overall fleet experience is favorable under Tier 1 in years 2004 and 2005, MDAD would then institute Tier 3 in year 2006 through 2010. Tier 3 involves the introduction of heavy trucks that have been upgraded for biodiesel use as part of normal engine rebuild cycles. Based on biodiesel fuel consumption levels estimated for Tiers 1 and 3 inclusive, the necessary biodiesel refueling infrastructure would consist only of one new 500 gallon aboveground tank and dispenser in Location O, and two refurbished 2,000 gallon tanks and dispenser at the 20th Street fuel facility location.

While the combined Tier 1 and 3 implementation presented here provides a reasonable introduction for biodiesel in MDAD's airside inventory, the equipment turnover schedule assumed for this study strongly influenced these final results. A different equipment turnover schedule than that assumed for this study could result in a slightly different implementation through 2010. For this reason, additional review and analysis of MDAD airside fleet needs is recommended for the period of 2004 through 2010 to "fine tune" the final recommended biodiesel implementation.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. STUDY BACKGROUND

1.1 MIAMI INTERNATIONAL AIRPORT OPERATIONS AND MANAGEMENT

Miami International Airport (MIA) is one of the primary air transportation hubs of the southeastern U.S. Among U.S. airports in operation in 2002, MIA ranked as the 12th largest for domestic passenger traffic, the third largest for domestic freight and the largest for international freight traffic. MIA has more than 90 resident airlines with flights to over 100 cities on four continents. The economic impact of MIA on south Florida exceeds $18 billion annually, and the airport provides about 237,000 jobs. MIA's regional importance will continue to grow based on South Florida population projections. In fact, MIA air cargo volume is projected to double over the next 20 years. Nearly 80% of cargo passing through MIA is international. Cargo movement to Latin America alone has increased by an average of 15% over the last five years, giving MIA the title of "Hub of the Americas."

To keep pace with this growth, the Miami-Dade Aviation Department (MDAD) has developed a $4.7 billion Capital Improvement Plan (CIP) outlining the necessary expansion and upgrade projects through year 2008. Major airside CIP projects include the creation of a new 47-gate linear concourse, expansion of cargo facilities by nearly three million square feet, and the creation of a fourth runway that will increase airfield capacity by 22%. As an interested community partner, however, MDAD is concerned with the potential impacts of noise, environmental issues, and increased energy use related to these expansion initiatives. In response to these concerns, MDAD has established a forward-looking goal for reducing airport-wide volatile organic compounds (VOC) emissions by 10% by 2010.

1.2 MDAD ALTERNATIVE FUELS MASTER PLAN AND BIODIESEL USE

MDAD is implementing an airport-wide plan to achieve these 2010 goals for VOC emission reductions. Several initiatives under this plan will include best management practices and implementation of advanced, more efficient, or alternative fuel technologies. One of these initiatives is the development of an Alternative Fuels Master Plan (AFMP) for MIA.

MDAD landside and airside operations currently consume more than 208,000 gallons of gasoline and 326,000 gallons of diesel fuel annually. The AFMP recommends a scheduled implementation of alternative fuel technologies across much of the MDAD airside and landside operations through year 2010. This technology implementation was derived based on an analysis of alternative fuels and technology options, current MDAD equipment inventories, and unique MIA operational procedures and parameters. The development of final technology recommendations was governed by the most cost-effective means of achieving the prescribed goal of reducing volatile organic compound (VOC) emissions from the MDAD equipment inventory. While mainly focused in the near-term on MDAD equipment and operations, it is hoped that the AFMP results will provide a clearly defined roadmap for MIA tenants to use alternative fuels in their operations in the future.

A variety of alternative fuels and advanced vehicle technologies was specified under the AFMP, as illustrated in Table 1-1. One of the key AFMP elements was the use of biodiesel in the MDAD diesel equipment inventory, mainly in heavy duty vehicle applications. Biodiesel is a fatty acid methyl or ethyl ester-based fuel that can be made from a variety of natural vegetable oils or recycled yellow grease (waste fryer oil from restaurants). Biodiesel in its pure form is registered as a diesel fuel additive with the U.S. Environmental Protection Agency's (EPA). The National Biodiesel Board, a biodiesel industry association, worked with the American Society for Testing and Materials (ASTM) to develop the ASTM specification D- 6751 for the biodiesel in the U.S. Neat (e.g. 100% pure) biodiesel contains no sulfur, aromatics, or metals, and has superior lubricity characteristics to conventional diesel fuel. It also has a high cetane value (a measure of the combustion quality of diesel fuels) which typically ranges between 49 and 62 based on its production feedstock. As such, biodiesel has become an excellent blending agent for conventional diesel fuel and is usually marketed as a B20 product, that is, a mixture of 20% biodiesel and 80% conventional diesel fuel.

TABLE 1-1. AFMP ALTERNATIVE FUEL RECOMMENDATIONS BY MDAD VEHICLE CATEGORY

MDAD Fleet Category	Alternative Fuel Technology
Automobiles	E85 and Hybrid-Electric
Light Duty Trucks	E85, Biodiesel, and Hybrid-Electric
Employee Shuttle Buses	Biodiesel
Baggage Tugs	Electric and Hybrid-Electric

The heavy-duty vehicles in the MDAD fleet consist mainly of diesel-powered light-duty pickup trucks, medium- and heavy-duty maintenance and construction trucks, grounds maintenance vehicles, and employee shuttle buses. The AFMP specifies biodiesel (B20) as the best solution for these vehicle classes because there is no incremental vehicle cost, refueling and facility costs are minimal if upgrading existing fuel storage tanks for biodiesel use, and the maintenance after the initial fuel switchover is the same as for diesel vehicles. The employee shuttle bus fleet is fueled at a landside location, while the remaining diesel vehicles are refueled at a separate airside location. As previously indicated, the MDAD fleet used 326,000 gallons of diesel fuel in 2003. Switching to B20 could potentially reduce petroleum fuel usage by 65,000 gallons annually.

1.3 NEED FOR BIODIESEL FEASIBILITY STUDY

While there is significant potential for biodiesel use in the MDAD diesel equipment inventory, there is a variety of operational and cost issues with biodiesel that should be addressed prior to widescale use of the fuel at the airport. For instance, a considerable portion of the MDAD equipment inventory is more than 10 years old. Original engine fuel system materials used in this age of equipment were not necessarily compatible with biodiesel blends which could lead to material breakdown and subsequent vehicle operational problems over time. In addition, while the AFMP identified significant potential for biodiesel use for MDAD vehicle applications on both the landside and airsides, only limited analysis was done concerning biodiesel use in airside stationary applications such as stand-by generators and fire pumps. In fact, little attention has been given to biodiesel use in stationary power generation applications in general. Biodiesel offers the same advantages to stationary power applications as vehicle applications in terms of conventional diesel fuel displacement, lower exhaust emissions, improved fuel lubricity characteristics (with its associated enhancement of engine lifetimes) and simple modifications for operating on the fuel. However, long-term biodiesel storage becomes a relevant issue for many of these stationary applications which are not operated frequently, including the MDAD generator and fire pump populations at MIA.

Based on these concerns, a biodiesel feasibility study was commissioned by MDAD to address these issues and provide recommendations for biodiesel implementation. This document presents the results of this study. The study covered the feasibility of using biodiesel fuels in MDAD airside equipment including back-up generators, fire pumps, baggage handling equipment, aircraft fuel trucks, and maintenance vehicles. This study reviewed both high- and low-level biodiesel blends to assess equipment fuel line materials compatibility issues, regional biodiesel product stability and quality, cost-effective power equipment applications, and airport fuel storage requirements and costs. The goal of this project is to provide recommendations for a phased implementation of biodiesel use in MDAD airside equipment over the next five to ten years, consistent with the CIP timeframe, as well as to assess the petroleum fuel savings and VOC reductions associated with this airside implementation. The study results will also provide back-up analysis and data for the AFMP and its projected landside biodiesel applications in employee shuttle buses and administrative/security vehicles.

1.4 COUNTY, STATE AND FEDERAL SUPPORT

Partial funding for this study was obtained from the U.S. Department of Energy through its State Energy Program with support from the Florida Energy Office in Tallahassee. Miami-Dade County's commitment to this study, the development of the AFMP for MIA, and the greater use of alternative fuels county-wide is evident. On April 10, 2001, the Board of County Commissioners passed Resolution R-378-01, which directed the County Manager to execute a Memorandum of Understanding with the U.S. Department of Energy redesignating Miami-Dade County as a member of the Gold Coast Clean Cities Coalition, a public/private coalition established by the Governor of Florida in 1993. Further, the Miami-

Dade County Alternative Fuels Advisory Committee (AFAC) was appointed in January 2002, drawing members from the Department of Environmental Resources Management, General Services Administration, Transit Agency, Aviation Department and Metropolitan Planning Organization. In September 2002, the AFAC submitted its Report and Recommendations to the County Commissioners, which covered a variety of alternative fuel-related initiatives, including the following related to biodiesel use in the County:

- "The Transit Agency should monitor the experience of other transit agencies with respect to the use of biodiesel fuel blends as a substitute for conventional diesel fuels… At current consumption rates, the annual cost to the County of replacing conventional diesel with B20 would be approximately $1.8 million with respect to the bus fleet. There may be a time in the future when biodiesel fuels become more competitive as world markets fluctuate and petroleum becomes scarce."
- The AFAC supported the effort of the Aviation Department to evaluate the use of biodiesel fuel in equipment used to service planes, noting that "the additional cost of using B20 biodiesel would be about $52,000 per year" and "would reduce greenhouse gas emissions by about 500 tons per year." (*Alternative Fuels Advisory Committee Report and Recommendations*, July 2002.)

1.5 STUDY CONTENTS

This document contains the results of a comprehensive feasibility analysis of biodiesel use in MDAD airside equipment. Section 1 contains this introduction. The remainder of the document presents a characterization of the current MDAD airside equipment inventory (Section 2), the status of the biodiesel supply in South Florida (Section 3), a discussion of the regional and national fleet experience to date with biodiesel (Section 4), an analysis of the use impacts of biodiesel (Section 5), an assessment of biodiesel storage issues (section 6), and recommendations for future biodiesel use in MDAD airside equipment applications through year 2010 (Section 7).

2. CURRENT MDAD BASELINE DIESEL EQUIPMENT INVENTORIES AND AIRSIDE OPERATION

The following describes the basic characteristics of the current MDAD equipment inventory serving MIA. The inventory represents calendar year 2003 and is a more current version than that used in development of the Alternative Fuels Master Plan (AFMP). The inventory served as the baseline to determine the range of biodiesel's applicability to MDAD operations. A detailed characterization of the current MDAD inventory and its baseline operational parameters is provided in Appendix A.

2.1 CURRENT EQUIPMENT INVENTORY

The MDAD equipment inventory consists of diverse mobile and stationary equipment supporting the needs of MIA and its tenant organizations. In total, MDAD operates more than 380 pieces of equipment. As described in Table 2-1, this inventory is made up primarily of mobile equipment. These include on-road vehicles for serving airside and landside operations, and non-road equipment such as baggage tugs, forklifts, tractors and lawnmowers. The majority of on-road vehicles is gasoline-fueled automobiles, pickup trucks, and sport utility vehicles (SUVs). MDAD also maintains 34 diesel-powered buses for shuttling MIA employees around airport grounds. However, since the focus of this study was the MDAD airside diesel equipment, the shuttle buses and other landside diesel equipment will not be discussed further in this report. A detailed assessment of the landside equipment of alternative fuel use was done for the AFMP. Note that a vast majority of the MDAD diesel vehicle population is from zero to ten years old.

TABLE 2-1 CURRENT MDAD AIRSIDE DIESEL EQUIPMENT INVENTORY AGE DISTRIBUTION

Vehicle Type	Vehicle Size	Number of Vehicles By Age					
		<5 yr	5-10 yr	11-15 yr	15+ yr	Totals	
Pickups	Full-size	17	11	0	0	28	**28**
Vans	Full-size	0	1	0	0	1	**1**
Trucks	Medium Duty	5	9	4	0	18	**35**
	Heavy Duty	4	8	3	2	17	
Maintenance Trucks	Various	13	10	6	1	30	**30**
Baggage Tugs[1]	---	5	5	7	0	17	**17**
Tractors/mowers	---	6	3	1	0	10	**10**
Generators[2]	---	---	8	19	21	48	**48**
Fire Pumps[3]	---	---	---	23	---	23	**23**
Totals		**50**	**55**	**40**	**24**	**192**	**192**

[1] Includes only gasoline-fueled baggage tugs that may be replaced with diesel hybrid models.
[2] Age distribution data not available. No information is available on nine (9) units, and only partial information on an additional 20.
[3] Age distribution data not available.

MDAD's stationary equipment consists of 48 diesel-engine-powered standby generators and 23 fire pumps. Generators range in size from 20 kilowatts (kW) to 2,000 kW. No detailed age distribution data was available for the generator and fire pump populations. However, an inspection of the standby generator (gen set) inventory and information gleaned from conversations with diesel equipment distributors established that many of the standby gen set drive engines represent older, now-outmoded technology. For example, there are at least ten generators driven by Caterpillar engines bearing three-digit model designations (e.g., 342, 343, 348, 379, 397, 399). These are all indirect-injection (IDI), or pre-chamber engines, that are no longer manufactured by Caterpillar, although the company continues to support existing units with parts and service. Production of some of these engines ceased as early as the late 1980s, according to a Caterpillar distributor representative. There are seven Caterpillar gen set engines in MIA's inventory of modern DI design - 3400- and 3500-series engines of 8, 12 or 16 cylinders. As the notes to Table 2-1 indicate, there are nine generators for which we have no information at all. These have somewhat arbitrarily been assigned, along with the discontinued Caterpillar engines, to the 15+-year-old "bin."

The situation regarding Cummins engines is similar. Cummins engines are found in gen sets built by that company, by Onan (now owned by Cummins), and by DMT Corp. The three Onan 4A2.3-series engines applied to DMT gen sets are on the order of 15-years old and probably IDI, according to a Cummins distributor representative. Engines designated KTA38 - there are four in the MIA inventory, in Cummins and Onan gen sets - were discontinued about four years ago. These seven engines have been assumed to be from 11- to 15-years old. A current-production Cummins engine has been assigned to the 5- to 10-year-old category. An engine described as a Cummins product in the generator inventory has a model number that our informant at Cummins did not recognize. This unit was assigned to the 15+-year-old category.

The largest-capacity MIA gen set (2,000 kW) is powered by an Electromotive Division (of General Motors) two-stroke cycle, medium-speed diesel. EMD produces these engines primarily for rail locomotive applications. Two-stroke-cycle diesels formerly dominated the transit bus market, primarily Detroit Diesel Corporation (DDC) products. Two-stroke engines have not been produced for on-highway use for nearly ten years, although they continue in rail, marine and some military applications. In general, engines employing this technology cannot meet current on-highway PM emissions regulations, and are considered obsolete for other than non-road applications. In view of the general vintage of this technology, we have assumed this unit is 15- or more years old.

The remaining twelve gensets are described as the products of various manufacturers, primarily John Deere. They are assumed to be from 11- to 15-years old, on average. We have also assumed an average age of 11- to 15-years for the fire pump drive engines. However, as these engines are typically used even less than standby generators and can remain serviceable for many years, this assumption probably understates the ages of these units.

2.2 BASELINE AIRSIDE DIESEL FLEET OPERATION AND PERFORMANCE

Current MDAD airside diesel equipment operational performance was assessed based on data collected on-site and interviews with key personnel. When data were not available for specific pieces of equipment, average values were used based on an evaluation of the remaining equipment in that category. Appendix A provides the comprehensive database of MDAD fleet operational data collected or estimated for this study.

Table 2-2 is a breakdown of MDAD equipment categories and average operational estimates for key parameters. Note that the categories with the oldest equipment on average are the baggage tugs, medium- and heavy-duty trucks. The categories with the highest equipment utilization rates (i.e., annual mileage or operating hours) are the pickups, vans, medium- and heavy-duty trucks, and tractors/mowers. The baggage tugs and tractors exhibit the highest average per-unit fuel use rates among MDAD equipment categories. The tractor/mower category values, however, were estimated based on the U.S. Environmental Protection Agency's (EPA's) Non-Road Emissions Model values since specific data on this MDAD equipment was not available. The generators and fire pumps are among the least utilized equipment due to their designation as standby units.

TABLE 2-2. AVERAGE OPERATIONAL PARAMETERS BY MDAD AIRSIDE EQUIPMENT CATEGORIES

Vehicle Type	Average Age	Average Annual Mileage/ Hours	Average Fuel Economy (mpg)	Average Annual Fuel Use (DGE)
Pickups	5	6,306	13.5	474
Van	5	5,592	10.0	559
Medium/Heavy Trucks	9	5,567	6.5	857
Maintenance Trucks	7	3,906	6.5	601
Baggage Tugs[1]	10	1,566	1.0	2,441
Tractors/mowers	5	722 hrs	0.1	1,147
Generators[2]	10+, estimated	43 hrs	---	398
Fire Pumps[2]	10+, estimated	24 hrs	---	109

[1] Only includes gasoline-fueled baggage tugs that may be replaced.
[2] Detailed age distribution data not available.

Based on the equipment breakdown and operational data, estimates of baseline fuel consumption and emissions for current MDAD inventory were derived. Fuel consumption estimates were calculated using model year-specific EPA city fuel economy ratings for on-road vehicles. In the case of non-road vehicles such baggage tugs, forklifts, tractors, and mowers, fuel consumption estimates were derived based on actual manufacturer equipment specifications or the use of fuel usage rates from the EPA Non-Road Emissions Model's equipment fuel use rates. Fuel consumption rates for the standby generators and fire pumps were estimated based on averaged operating hours from two 18-month summaries, engine characteristics and fuel properties.

Table 2-3 lists the baseline fuel estimates for each of the MDAD airside diesel equipment categories. A total of 139,353 diesel-gallon-equivalents (DGE) was estimated[1]. The highest overall baseline fuel use for any category was estimated for the baggage tugs at DGE, or 29.8 percent of the MDAD inventory's annual fuel consumption. The second-largest diesel fuel users within the MDAD airside inventory are the medium- and heavy-duty trucks, with 29,121 DGE, or 20.9 percent of annual MDAD inventory fuel usage.

TABLE 2-3. BASELINE ESTIMATES OF MDAD AIRSIDE INVENTORY FUEL USAGE AND EMISSIONS

Vehicle Type	Total Estimated Annual Fuel Use (DGE)	Total Estimated Emissions (tons/year)				
		VOC	**CO**	**NOx**	**PM**	**CO2**
Pickups	13,752	0.13	0.22	0.29	0.03	119.0
Vans	559	0.00	0.01	0.01	0.00	4.10
Medium/Heavy Trucks	29,121	0.10	0.56	3.22	0.07	278.9
Maintenance Trucks	18,827	0.09	0.49	2.85	0.07	246.1
Baggage Tugs	41,505	0.96	40.34	0.41	0.00	---[1]
Tractors/Mowers	11,470	0.45	1.62	2.14	0.28	---[1]
Generators	21,321	0.4	1.2	5.4	0.4	202
Fire Pumps	2,798	0.1	0.2	0.7	0.1	26.5
Baseline Totals	**139,353**	**2.23**	**44.64**	**15.02**	**0.95**	**876.6**

[1] Estimates of CO2 emissions were not available due to lack of appropriate calculation factors.

Table 2-3 also provides the baseline emission estimates derived for the current MDAD inventory. For the on-road vehicle categories (namely: pickups, vans, medium/heavy trucks, maintenance trucks), emissions estimates were developed using the EPA MOBILE6 vehicle emissions model. MOBILE6 baseline emission factors (grams/mile, g/mi) were developed based on a variety of model inputs unique to MIA, including ambient temperatures, regional gasoline volatility, and current MDAD fleet make-up and usage for VOC (exhaust and evaporative), CO, NOx, PM (carbon fraction, gas fraction, lead, tire, and brake), and CO_2 emissions. Mass emission estimates for the on-road categories were then calculated by applying the MOBILE6 factors to the annual mileages associated with the individual categories.

Baseline emission estimates for the MDAD non-road categories (baggage tugs, tractors, mowers, generators, and fire pumps) were developed from manufacturer emission certification figures (g/bhp-hr), EPA Non-Road Emission Model, or EPA AP-42 emission factors. The EPA Non-Road Emission Model provides VOC, CO, NOx and PM emission factors (lb/bhp-hr) based on engine size and load factor inputs. AP-42 provides emission factors ($lb/MMBtu_{fuel\ input}$) for

[1] Diesel gallon equivalent, DGE, is a convenient means of presenting overall fuel usage when comparing conventional fuels with biodiesel or other alternative fuel. In the case of MDAD baseline fuel use, total DGE incorporates both gasoline and diesel fuel usage figures. The gasoline fuel usage (for the baggage tugs) was converted to DGE based on the respective energy contents (BTU/gallon) of diesel fuel and gasoline. Similarly, later in this document biodiesel fuel usage will be represented in DGE after conversion using the respective energy contents of the various biodiesel blends and diesel fuel.

VOC, CO, NOx, PM and CO_2. Mass emissions for these non-road categories were estimated by applying the emission factors obtained from one of these sources to appropriate MDAD operational parameters such as annual hours, engine power rating, or annual fuel usage.

Note that the current MDAD airside diesel equipment inventory was estimated to produce about 2.2 ton/yr VOC, 44.6 ton/yr CO, 15.0 ton/yr NOx, 0.95 ton/yr PM. The largest VOC emitters among the MDAD equipment categories were the baggage tugs (1.0 ton/yr), the mowers/tractors (0.5 ton/yr), and the standby generators (0.4 ton/yr). The VOC emissions from these three categories combined constitutes about 81 percent of the total VOC emissions of the MDAD airside inventory.

3. SOUTH FLORIDA REGIONAL BIODIESEL FUEL SUPPLY

Biodiesel has been available in South Florida and in use by regional fleets for several years. This section discusses the regional biodiesel supply from the perspective of a fleet user's main concerns.

3.1 SUPPLIERS: CURRENT AND PROSPECTIVE

Several South Florida fuel dealers were identified in the course of this study who can supply biodiesel blends. The market has been fairly dynamic in the past two years, with at least one Florida biodiesel production facility changing ownership and commencing and suspending production several times. Streicher Mobile Fueling (Fort Lauderdale) supplies biodiesel to the U.S. Postal Service fleet of over a thousand vehicles in the South Florida area. BV Oil, Inc. ,located in Miami, can also provide biodiesel blends. BV Oil has supplied B20 to the Water Taxi, Inc. fleet and has been the source of periodic samples of both B100 and conventional diesel fuel in this study. The company is also a current vendor of conventional fuels to Miami-Dade County. There are undoubtedly other suppliers currently active in South Florida, and others will enter the market as it grows. If MDAD elects to commence using B20, the County's other fuel vendors would probably have no difficulty finding local sources of the necessary B100.

3.2 BIODIESEL FEEDSTOCKS

In the U.S., the use of fatty acid alkyl esters (biodiesel) as engine fuel was originally conceived as a means to create a new market for soybean derivatives, in this case, soybean oil. Soy oil is the dominant biodiesel feedstock in the U.S. and this is unlikely to change in the foreseeable future. Rape (*Brassica napus*), a member of the cabbage family also known as colza, is widely grown in Europe and the oil of its seeds is the dominant biodiesel feedstock there. A venture was recently proposed to grow rape in the Northern Plains states for processing into biodiesel. Low-erucic acid rape, sometimes known as canola (for CANadian Oil, Low Acid) is widely grown in Canada and in the Northern Tier states. Rapeseed oil produces a somewhat more saturated biodiesel, which makes it marginally less suited to cold climate usage, but potentially more stable at high temperatures and in storage. Virgin vegetable oils tend to have low levels of free fatty acids and can be processed into biodiesel by base-catalyzed transesterification, the predominant technology in current use. Soybean oil is the principal biodiesel feedstock at the sole production facility in Florida, the Purada Energy plant in Lakeland, Florida.

A second feedstock that can achieve significant usage in specific locales and markets is yellow grease. This is cooking oil from commercial food preparation operations such as restaurants. Yellow grease may consist of various vegetable oils. It normally finds its way into livestock rations. In urban areas particularly, the supply of yellow grease can be substantial and it can be a significant biodiesel feedstock in some areas, particularly if there are local production facilities. Because yellow grease will have been repeatedly and strongly heated during its service life, it will be oxidized to some extent. It will have absorbed various extraneous materials, including water, from the foods cooked in it. It also typically has higher levels of free fatty acids than virgin vegetable oils. This may call for additional pre-processing and careful quality control of the finished biodiesel product. However, there is no technical reason that biodiesel meeting the ASTM specification cannot be made from yellow grease.

3.3 ADDITIVES FOR BIODIESEL AND BIODIESEL BLENDS

There is no general agreement at this time on what additives, if any, may be required for biodiesel (B100) or its blends with petroleum diesel fuel. Likewise, it is not clear at present to what extent additives used in conventional diesel fuel will also be effective in biodiesel blends. Additives to improve the cold weather handling of biodiesel blends will obviously not be necessary in the warm South Florida environment. When long-term storage of biodiesel fuels (or conventional diesel fuel, in many cases) is contemplated, it is generally recommended that antioxidants be employed to stabilize the fuel against oxidation, and biocides may be needed to suppress biological activity. If biodiesel blend usage is confined to applications not requiring long-term fuel storage neither problem is apt to arise. Thus, fuel additization with antioxidants and microbiocides beyond what the base diesel contains is unlikely to be necessary in those cases.

The National Biodiesel Board (NBB) sponsored some testing of antioxidant additives for biodiesel (NBB/System Lab Services, 1997). According to their report, "Biodiesel oxidizes by different chemical mechanisms than the mechanisms associated with diesel fuel instability. This makes the application of much of the research relative to diesel fuel stability inappropriate." Three additives were tested, alone and in combinations in the NBB/System Lab Services program. They included tertiary-butyl hydroquinone (TBHQ) and two proprietary additives developed for and used in petroleum fuels. Biodiesel appeared to promote sediment formation in petroleum diesel fuel at the same time the petroleum additives were hindering formation of insolubles in the petroleum fraction. One of the additives appeared actually to *promote* development of sediment in the diesel fuel fraction of the blend fuel.

There is currently no practical field test that can be used to monitor the stability of biodiesel blends. However, it may be possible to assess the condition of B100 by determining its acid number (12). [Numbers in parentheses refer to references in Appendix E, "Materials Compatibility Bibliography".] The acid number value specified in the ASTM biodiesel specification may be exceeded before B100 begins to form insolubles that appear as fuel sediment. Further field experience will be required to establish the usefulness of acid number determinations for this purpose. In any event, this test is not likely to be applicable to biodiesel blend fuels. Work is underway to identify ways in which existing oxidative and storage stability tests could be modified to make them suitable for use with biodiesel and biodiesel blends. Given the sheer volume of research and testing that will have to be done before such a test can be identified, proved and adopted, no practical test is apt to emerge in the next five years. In the meantime, biodiesel users will have to rely (and insist) on adherence to the current ASTM specification (D 6751) by their fuel suppliers and limit their use of biodiesel fuels to applications that do not require blended fuels to remain in storage longer than three months.

At this time, it is difficult to make definitive recommendations regarding additization of B100. Wax modifier additives and pour point depressants are unlikely to be necessary in South

Florida's mild-to-warm climate, and in any case, when such additives are used, they are generally blended to diesel fuels.

When long-term (more than six-months) fuel storage is anticipated, antioxidants or other stabilizer additives may be advisable. The same may be true for anti-microbial additives, given the ready biodegradability of biodiesel. However, long-term storage of B100 is not recommended, and we have suggested that MDAD not apply B20 where storage for longer than two months is likely, until some operating experience with the blended fuel has been acquired. Because biodiesel and petroleum hydrocarbons degrade by different chemical mechanisms, stabilizer additives in the base diesel fuel may or may not be effective in stabilizing the biodiesel fraction of a blend. Bayer Chemicals has begun marketing an antioxidant additive – Baynox® Biodiesel Stabilizer - expressly designed to be used with biodiesel. Similar to alpha-tocopherol (vitamin E), which has also been tested as a stabilizer additive, Bayer's product is claimed to be more effective. The product is in use in Europe, where colza (rapeseed)-based biodiesel is the norm and where the governing product specification contains an oxidative stability requirement. In the U.S, soybean oil is the dominant biodiesel feedstock, and the ASTM specification provides no stability test procedure. Since any additive which is not required under MDAD's current fuel specification will increase the cost of the fuel, it is advisable to allow operating experience to dictate the need, if any, for additional additives.

If biocides are used, they are best applied with the initial fill of biodiesel-blended fuel. This will kill any existing micro-organisms and suppress their growth for some weeks or months. After the initial fill, keeping water accumulation to a minimum will probably provide adequate protection against microbial regrowth.

3.4 PRICES – CURRENT AND HISTORIC

Figure 3-1 illustrates the prices of biodiesel and diesel fuel over the past year in the Miami area. Biodiesel prices will respond to some degree to factors influencing the price of soybeans, since soy oil is the predominant biodiesel feedstock. We found anecdotal evidence that the price of B100 had risen to about $2.55 per gallon late in 2003, apparently in response to a rise in soybean prices on the world

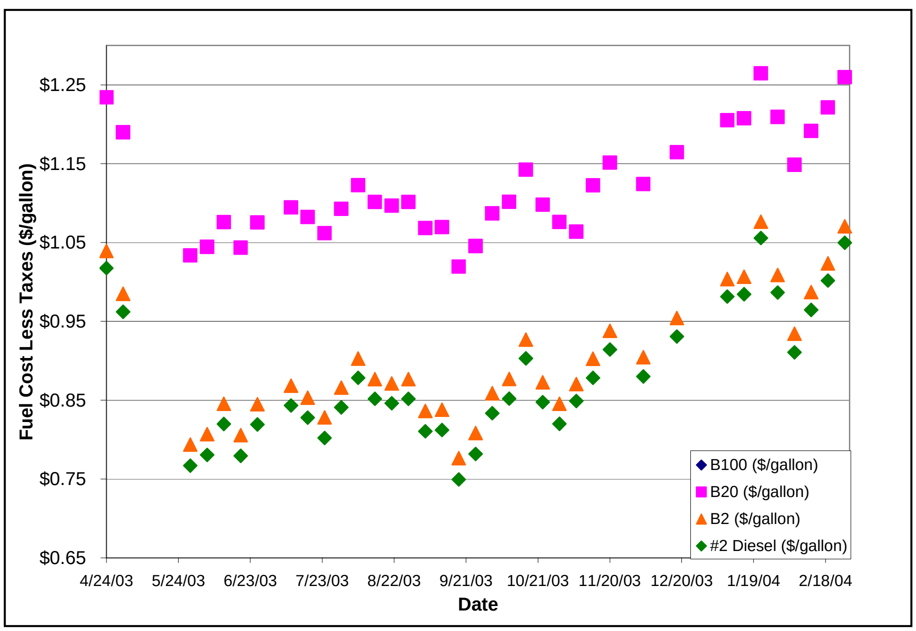


Figure 3-1 Diesel and biodiesel prices in Miami 2003-2004.

market. Since Miami-Dade County purchases fuel weekly, essentially on the spot market, it may be more vulnerable to such price spikes than if it acquired fuel under longer-term contracts. Barring unusual circumstances, it is unlikely that B100 will be available at prices below $2.00 a gallon in the foreseeable future.

3.5 BIODIESEL FUEL QUALITY

To aid in assessing the quality of biodiesel fuel available in the Miami area, and its variability, Panair Laboratory, Inc. was contracted to acquire samples of B100 and low-sulfur (500 ppm) diesel fuel twice monthly from BV Oil. Panair prepared a B20 blend from these materials. They tested both the B100 and the B20 to determine acid number (ASTM Test Method D 974) and water and sediment content (ASTM Test Method D 2709). Acid number provides an indication of the extent to which the B100 has undergone chemical reactions characteristic of oxidation, such as might occur in storage. Water and sediment, as the name suggests, indicates the extent to which the fuel samples are contaminated with water and insoluble material. Tests of these bi-weekly samples serve to give a series of "snapshots" of typical, commercially available biodiesel quality in the Miami area. The results are graphed in Figures 3-2 (B100) and 3-3 (B20), below. All values for B100 are well below the respective upper limits specified in ASTM D 6751 – 0.80 mg KOH per gram of B100 for acid number and 0.50 volume percent for water and sediment. This suggests commercially available B100 in the Miami area is routinely meeting the ASTM specifications for these parameters. The results for B20 show the effect of diluting B100 with four times its volume of diesel fuel; variations of B100 properties are moderated considerably.

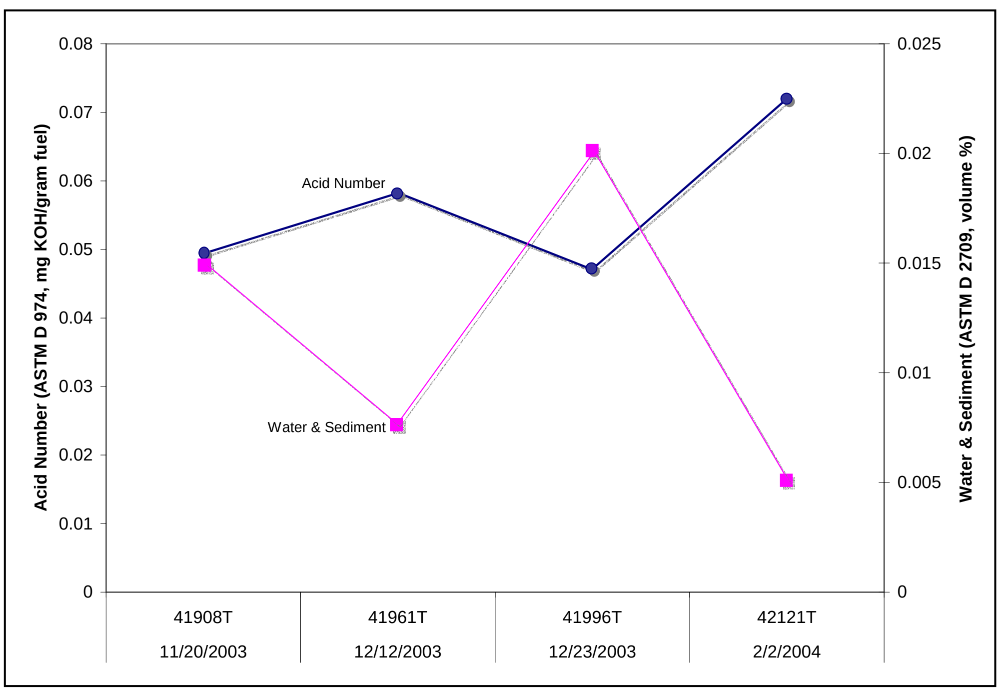


Figure 3-2. Quality measures of commercial Miami area B100 fuel.

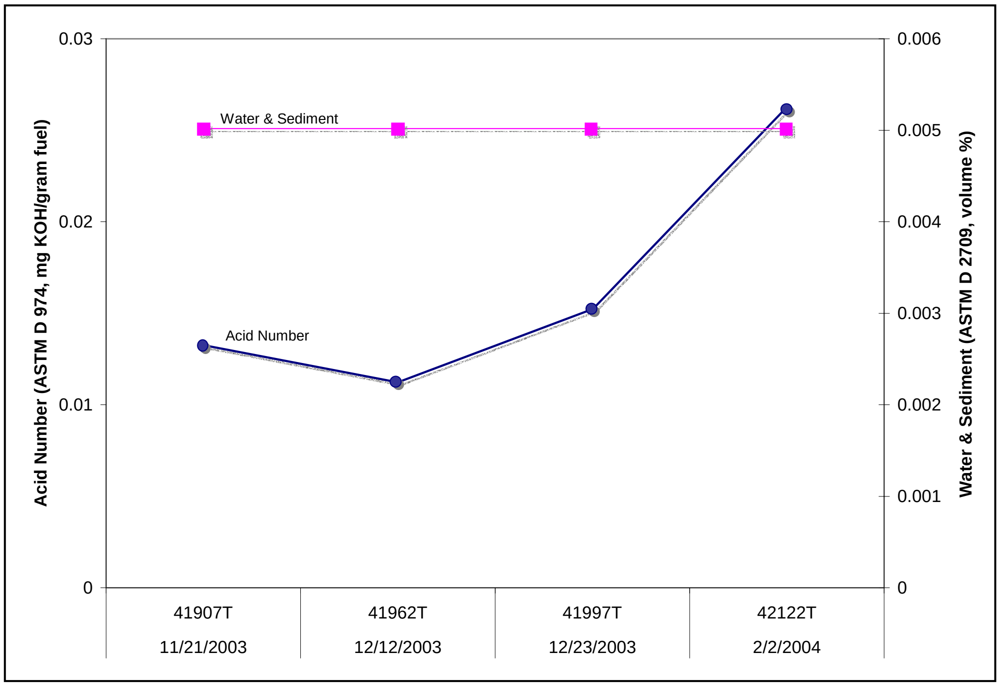


Figure 3-3. Quality Measures of B20 fuel prepared from commercial area Miami area blend stocks.

The first sample of B100 collected (on November 20, 2003) was larger than subsequent samples to permit additional tests to be made on it as it aged under mild (room-temperature) storage conditions at the Panair Lab. It was hoped that monthly acid number determinations on this material would provide some indication of the rapidity with which it underwent chemical changes characteristic of aging. The results of the tests made to date are summarized in Figure 3-4, below. The testing is ongoing, and definitive conclusions cannot be drawn based on the information collected to date. However, subsequent monthly tests of B100 showed acid numbers increasing from an initial value of 0.049 (milligrams of potassium hydroxide per gram of B100) to a value of 0.167 by the fourth test. These values are all within the limit (0.80) imposed by ASTM D 6751, but provide evidence that the stored B100 is indeed undergoing chemical changes. (The acid number test in the ASTM specification is slightly different from the one used in this testing, but the results are comparable and reported in the same units – mg KOH per g sample.) Figure 3-5 shows once again that diluting B100 with four times its volume of diesel fuel moderates and masks changes the B100 has undergone. The B20 tests graphed in Figure 3-4 represent blends made with the aging B100.

While these preliminary indications are positive, anecdotal evidence came to light in discussions with fuel suppliers indicating there have been fuel quality upsets in the past. For a period of some months, one fuel supplier typically found that an 8,000-gallon delivery of B100 to his tank would leave a “heel” of up to 300 gallons of dark, cloudy material unfit for sale. The nature and origin of the contamination is unknown. Other quality upsets we have heard of appear to be one-time occurrences related to the initial introduction of B100 into tankage, transport vehicles, etc. formerly dedicated to petroleum-based fuels. This underscores the importance of compliance

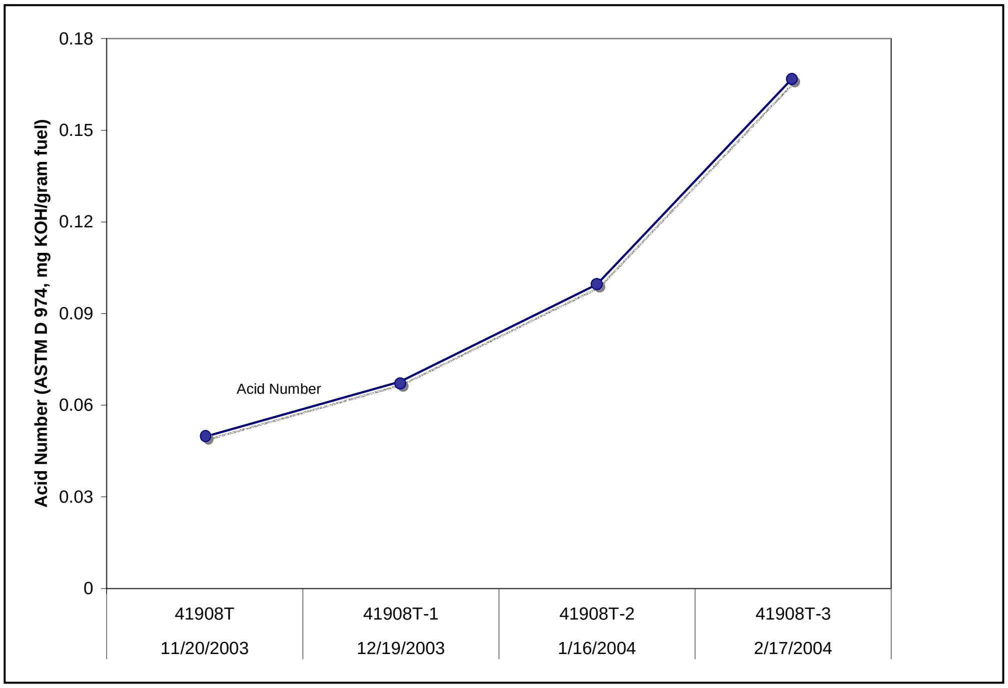


Figure 3-4. Acid number change of stored B100 fuel sample.

with the ASTM specification at the time and place of blending. It also suggests that biodiesel is best purchased from suppliers familiar with and experienced in handling it. Fatty acid methyl esters are marketed under various trade names (e.g., Ag Environmental Product LLC's SoyGold®) as industrial solvents. Blending with 80 percent petroleum diesel fuel moderates FAME's solvency, but it nevertheless remains capable of loosening dirt and asphaltene deposits in petroleum systems. This action may also mobilize fine rust particles and other debris, degrading fuel quality and potentially causing damage to downstream equipment. We have heard of one case in which the introduction of biodiesel caused a rash of diesel engine fuel injector failures, perhaps by this mechanism, although that is unclear. This possibility is why we strongly suggest not only that fuel filters be changed regularly during the transition to biodiesel blends, but that the finest available filtration - two to five microns - be used during this period.

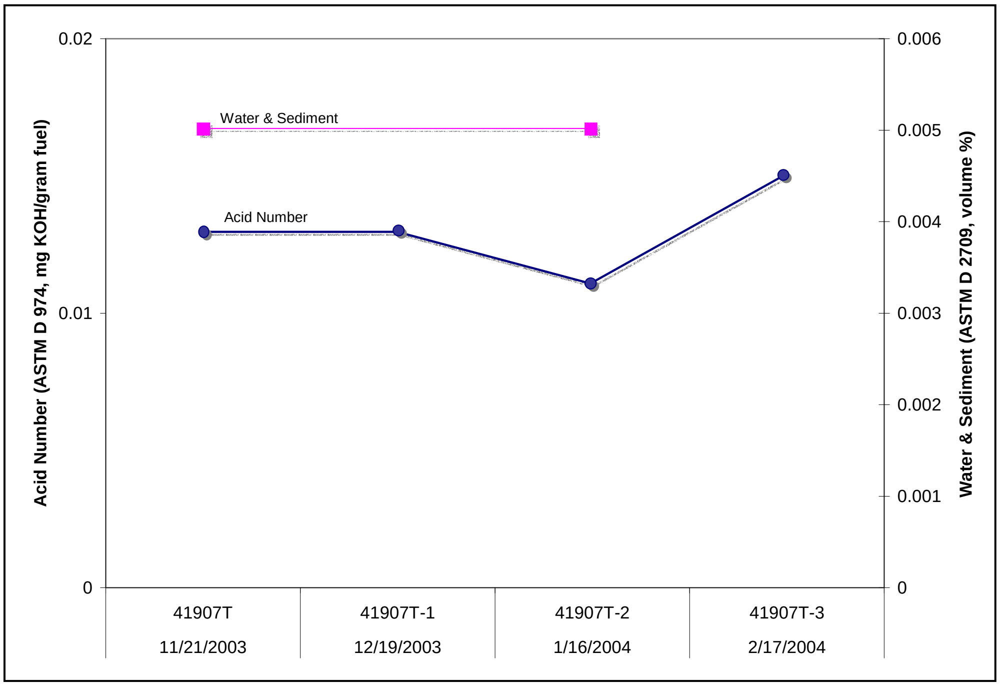


Figure 3-5. Quality measures of B20 fuel prepared from stored B100 fuel sample.

4. REGIONAL AND NATIONAL BIODIESEL FLEET EXPERIENCE

Over the past several years, an increasing number of fleets nationwide have experimented with various biodiesel blends, and a few have used B100. Many of these fleets have adopted biodiesel fuel(s) in part or all of their operations. The majority of biodiesel use programs, not surprisingly, have been in the Midwest, where soybeans are an important crop. However, interest in this renewable fuel is growing and several major producers can supply product virtually anywhere in the U.S. There are several examples of biodiesel use by fleets in South Florida as well.

Fleets covered by the Energy Policy Act of 1992 (EPAct) have used biodiesel purchases to gain partial credit toward their alternative fuel vehicle (AFV) acquisition requirements under the Act. An amendment to EPAct, the Energy Conservation Reauthorization Act of 1998 (Public Law 105-388) permits each 450 gallons of B100 used by a fleet (in at least a 20-volume-percent blend) to be credited as one additional AFV acquisition under EPAct for fleets that have satisfied their obligation to acquire light-duty AFVs. Credits may be traded to other EPAct-covered fleets.

The majority of reported fleet experience with biodiesel has been positive. Many fleet operators, including some we spoke with in the course of this investigation, emphasized the straightforward nature of substituting a biodiesel blend for their customary petroleum diesel fuel, and the general absence of serious problems. However, there is also anecdotal evidence that the move to a biodiesel-blended diesel fuel is not always or necessarily a “slam dunk.” The properties of biodiesel differ sufficiently from those of conventional diesel fuel, and in enough key respects, to make it imperative that fleet operators understand and plan to avoid the most disruptive problems that can potentially accompany biodiesel introduction to their operations.

4.1 SOUTH FLORIDA FLEET USE OF BIODIESEL

Two South Florida fleets known to have used, or to be using biodiesel are Water Taxi, Inc. (651 Seabreeze Boulevard in Ft. Lauderdale) and the U.S. Postal Service (USPS) fleet in various South Florida locations. Mr. Robert Berkoff of Water Taxi emphasized that the introduction of biodiesel to that company’s fleet had been substantially trouble-free, with the exception of one or two instances of elastomeric material incompatibility with biodiesel. They also experienced a fuel contamination incident; although Mr. Berkoff doubted the contaminant was native to the B20 fuel itself, believing the foreign material originated in a fuel dealer tankwagon. Our contact at the USPS vehicle maintenance facility, Mr. Les Machek, stressed that tankage dedicated to straight biodiesel (B100) had to be kept clean and dewatered to forestall biological growth. In mid-2003, the USPS fleet was using some 10,000 gallons of B20 per month, an amount sufficient to justify their dedicating an on-site tank to B100.

The Florida Department of Environmental Protection (DEP) announced in mid-January 2004 it would begin using biodiesel in trucks operated by its Office of Greenways and Trails. The trucks are used to tow tractors and heavy-duty maintenance equipment along the Cross Florida Greenway, as well as over paved highways.

4.2 FEDERAL FLEET BIODIESEL EXPERIENCE

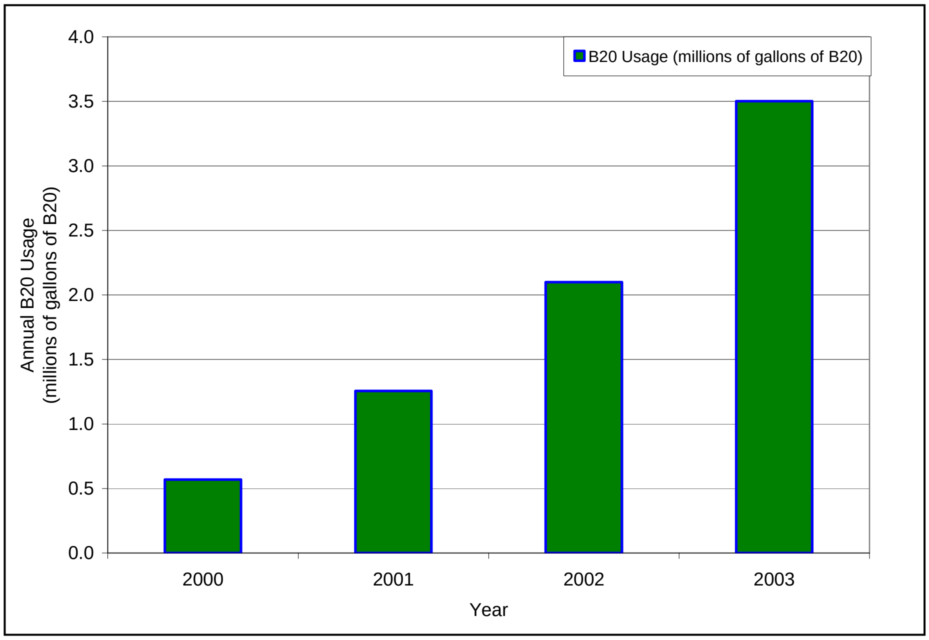


Figure 4-1. Growth of biodiesel use in Federal fleets.

Some Federal fleets have been using biodiesel blends (B20) since 2000 and there has been an increasing trend since. Figure 4-1 shows the increase in annual biodiesel fuel usage from 2000 to 2003 for all Federal fleets. The majority of the fuel (~71%) in 2003 - 2.5-million gallons out of 3.5-million gallons - was used by four fleets, the Departments of Agriculture and Interior, the Department of the Air Force and the U.S. Postal Service. The National Park Service (NPS) has used biodiesel (up to B100) to reduce petroleum use in most types of equipment from mowers to construction equipment to vehicles to power generation. NPS regards the environmental impact of biodiesel as lower than petroleum diesel and biodiesel is more biodegradable. The NPS has also tested the effects of the fuel in climates from Hilo, Hawaii to the Grand Teton National Park in Wyoming. Their experience has been good, with only a handful of problems arising, mainly materials compatibility with B100.

5. BIODIESEL USE IMPACTS FOR MDAD AIRSIDE EQUIPMENT AND PERFORMANCE

5.1 FUEL SYSTEM MATERIALS COMPATIBILITY

Many papers have been published on the effects of biodiesel or biodiesel blended fuels on engine performance, wear and emissions. A smaller number of papers have discussed the fuel system and storage tank material compatibility issues of using biodiesel in systems designed for diesel fuel. Several studies report end-user field test emissions, maintenance and engine wear data from using biodiesel on particular vehicles. Other studies focused on testing the physical property changes elastomeric materials undergo and the effects of metals in biodiesel, petroleum diesel, and fuels blended from the two. The study team examined this body of technical literature, the most relevant items from which are summarized below. In addition, the study team undertook to test the effects of a B20 blend and the base diesel fuel from which it was blended on three selected elastomers typical of those found in diesel engine fuel systems. That program is discussed in the next part of this section.

Reed, in his 1993 paper, discusses material compatibility testing done by Pischinger in 1982 showing that biodiesel did not cause degradation of steel, brass, aluminum, and phosphated storage tanks (1). [Numbers in parentheses refer to references in Appendix E, "Materials Compatibility Bibliography".] The same study also tested ten common polymer materials. Only nitrile rubber and polyurethane were found to be problematic.

Holmberg discusses testing of transit bus engines in 1993 on B30 and found "no instances of fuel system degradation" (2). He commented further that "it appears that possible material compatibility issues for higher blends can be readily resolved."

Spataru in 1995 tested the emissions and performance of a Detroit Diesel transit bus engine (DDC 6V-92TA MUI (mechanical unit injectors) produced through 1989) on biodiesel. Only materials in the fuel pumping/mixing station were tested for degradation with biodiesel (3). A sample of B100 was sealed in a ten-inch-long section of the polyurethane tubing for 5 months at room temperature. The biodiesel "sweated through" the tube in two months, indicating that polyurethane is not suitable for biodiesel, at least not with B100.

A pair of Dodge pickups (1991 and 1992) with Cummins 5.9-liter engines was tested using B100 by Schumacher in 1996. The trucks accumulated a combined 100,000 miles (4). The study compared their emissions and operating performance on biodiesel versus conventional diesel. The original nitrile rubber hoses in the 1991 engine deteriorated and were replaced with either Viton (fluorinated rubber), aluminum, or nylon-reinforced tubing. Cummins was involved in the project and disassembled the 1992 engine at the end of the project to measure wear. The connecting rods, crankshaft, camshaft, pistons, piston pins, and piston rings all showed the engine was wearing at a rate consistent with running on diesel fuel. A slight increase in compression ring deposits was seen, but this was determined to be the result of light-load operation for the last 80,000 km of use.

Bessee performed a comprehensive literature review and study for the U.S. Army in 1997, testing both elastomers and metals in biodiesel fuels (5). The materials compatibility testing investigated the performance and degradation of a variety of common automotive elastomers and metals. Samples were tested in fuels including JP-8, B100, low-sulfur diesel, ASTM No. 2 reference fuel, ASTM No. 2 low-sulfur reference fuel, and 20 and 30 volume percent biodiesel blends. The biodiesel blends were based on JP-8, LSDF, and No. 2 reference fuels. Each test fuel was analyzed to determine its characteristics and compliance to the relevant specification. Elastomers included Teflon, Nylon 6/6, Viton A401C, Viton GFLT, fluorosilicone, polyurethane, and polypropylene. Teflon is used in many fuel systems for its inertness. Nylon 6/6 was selected because it is used in the fuel cell variant of the Bradley Fighting Vehicle and has been problematic. Nitrile rubber is a common material in automotive fuel systems and has performed poorly in biodiesel in several studies. Viton A401C is a general-purpose fluoroelastomer commonly used in automotive fuel systems. Viton GFLT is a specialty product with the best low-temperature flexibility and enhanced fluid resistance properties. It is commonly used in automotive fuel systems. Fluorosilicone, polyurethane, and polypropylene are used throughout fuel system in o-rings, gaskets, and hoses. Bessee identified tensile strength as the key physical property to determine biodiesel's effects on elastomer properties. Nitrile rubber performed worst, as expected from previous testing and field data. Polypropylene performed second worst of all the materials, losing 27% of its tensile strength. Metal coupons of C110 copper, SAE 1010 steel, C260 brass, 6061 aluminum, A319 cast aluminum, and C510 bronze were immersed in the various fuels. The physical changes to the fuels and coupons, including gum formation and corrosion, were noted and total acid number (TAN) was measured after six months. Figure 5-1 shows changes in the surface color of copper coupons in the test fuels after six months' exposure. A higher TAN may lead to increased corrosion rates of various parts in the fuel system. Steel and aluminum promoted the highest TANs, even though there was no gum formation nor surface visible surface corrosion of the metal coupons. In general, the B100, and biodiesel blends in JP-8 and LSDF showed dramatic increases in TAN. The standard diesel, JP-8 and ASTM reference fuels showed very small changes in TAN over the six months for all of the test materials.

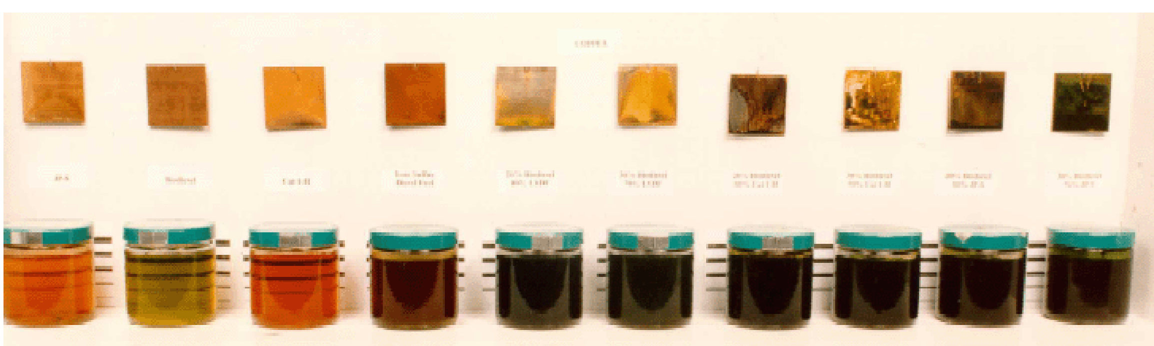


Figure 5-1. Fuels and copper coupons after six-months aging at 51.6ºC.

Harrigan discussed an overall approach in 2000 for testing fuel systems materials. Biodiesel is mentioned, but not discussed in detail (6). Volume swell rather than tensile strength is suggested as the key physical property to measure and track, "in the case of fuel system materials volume swell is used as a reliable indicator of the general effect a solvent will have on polymers and elastomers." This suggests a combination of volume swell and tensile may provide the most useful results.

Chase discusses a 100,000-mile test done by Peterson on a 1992 Dodge pickup running on approximately a B30 blend made with HySEE rapeseed methyl ester (RME) (7). Material compatibility was not discussed, but the original equipment rubber fuel lines were replaced with Viton hoses at the start of the project to reduce risk of deterioration of. The fuel filter was changed 13 times over four years and 160,000 km. Peterson noted that "rust formation and filter plugging prompted a change from mild steel fuel and mixing tanks to stainless steel." He added that some of the plugging may have been due to the effects of cold weather on the fuel. In another paper, Peterson investigated the use of HySEE blends from B25 to B100 in a three-cylinder diesel gen set. Results showed reduced wear metals. Teardown of the Caterpillar 3406E engine tested by Chase in 2000 found the wear to be within spec and the projected life for the engine to be 200,000 miles. No significant build-up of carbon or other foreign material was found inside the injectors, nor was there any unusual wear in the valvetrain.

Maxson, et al. of Dow Corning in 2001 investigated the performance of fluorosilicone automotive fuel system materials exposed to European rapeseed-based biodiesel fuels (8). The paper describes two studies. The first was a screening test to assess the effects of immersion for 168 hours (one week) in various fuels from pure diesel to B100 on a high-durometer (75) fluorosilicone. The high-modulus fluorosilicone (FVMQ) selected is typical of elastomers used to make O-rings for automotive fuel line quick-disconnects. Testing was done to determine the effects of hot diesel fuel on elastomer properties and to identify the most aggressive fuel blend. All test fluids produced similar results, but the B25 blend with the addition of trace water and metals was selected for longer-term testing since it had slightly more effect on elastomer property degradation. Samples were placed in this liquid for 4,032 hours (24 weeks). There were no large additional property changes during the long-term exposure, showing that high-modulus materials are not heavily affected by biodiesel and that most degradation occurs in the first several hundred hours, as shown in the first phase of testing. The second study tested two fluorosilicone samples of lower hardness {40 and 60 durometer), and a liquid silicone rubber (LSR) material in B100. High-durometer materials are more resistant to fuel degradation, but are not always used in all parts of the fuel system. Both lower-durometer materials performed well, losing 20% to 30% of their initial tensile strength; the LSR lost approximately 50% of its tensile strength. Maxson commented on the LSR's loss of strength, saying "However, a 15% volume change and a loss of 40 to 50% in elongation and tensile strength are not unreasonable for many elastomers and exposed to automotive gasoline type fuels in-service."

Crouse (Dana Corporation) discusses the effects of biodiesel on the physical properties of thermoset elastomers in a 2002 paper (9). The paper compares the performance of several common automotive elastomer materials in diesel fuel, ASTM Fluid 2 (50% toluene/50% isooctane), and B100 (both rapeseed methyl ester, RME and soybean methyl ester, SME). There is generally good agreement between the RME and SME tests. The materials tested were nitrile butadiene rubber (NBR), NBR fluxed with polyvinyl chloride (NBR/PVC), Homo-, co-, and ter-epichlorohydrin, and fluorinated polymers (FKM). NBR is a traditional fuel-resistant elastomer used in automotive and marine applications. NBR/PVC has better ozone resistance than NBR alone. Homo-, co-, and ter-epichlorohydrin polymers cover a wide range of fuel resistance, air-aging and cost, ensuring their wide usage in the automotive market. Fluorinated polymers (FKM) are used for their outstanding resistance to oxidation, fluids and heat. All the materials performed well except the NBR/PVC, which had borderline performance, showing a 27% reduction in tensile strength.

DuPont Dow Elastomers has tested their Viton elastomer using biodiesel and reported the material "has shown its excellent resistance to swelling and property degradation in both low-sulfur and bio-diesel fuels (10). This performance identifies Viton as an excellent candidate for diesel fuel system components in the future."

The Fuel Injection Equipment (FIE) Manufacturers Association, which includes Delphi, Stanadyne, Denso, and Bosch, released a Common Position Statement in June 2000 regarding the use of biodiesel in engines designed for diesel fuel (11). The statement raises the group's concerns that need to be resolved before the introduction of the fuel to protect the manufacturers and the end-users. This was not done with California's introduction of low-sulfur "CARB diesel fuel," and lowered fuel lubricity caused some fuel pump problems. A copy of the statement is included in Appendix B, which covers all of the specific concerns with biodiesel production and use. The German DIN51606 and ASTM D 6751 (12) standards cover most of the concerns. FIE's final recommendation is that use of blends up to 5% biodiesel should not cause any problems, but the FIE manufacturers accept no legal liability for failures attributable to operating their equipment on fuels other than the ones they were designed for (diesel), even if the fuel meets the appropriate specs. The same argument is used if an engine is run on a bad batch of diesel fuel. No warranties are given in this case.

The Engine Manufacturers Association (EMA) released a Technical Statement regarding using biodiesel in diesel engines in February 2003 (13). They cite the above FIE statement, and concur that blends of a maximum of 5% biodiesel "should not cause engine or fuel system problems, provided the B100 used in the blend meets the requirements of ASTM D6751, DIN 51606, or EN 14214. If blends exceeding B5 are desired, vehicle owners and operators should consult their engine manufacturer regarding implications of using such a fuel." A copy of the statement is included in Appendix G.

The diesel engine manufacturers each have a separate position on the use of biodiesel beyond what the EMA statement covers. In general, their positions align closely with the EMA statement, but the acceptable percentage blends range from B5 to B20. Several manufacturers have a list of specific maintenance and service concerns related to using biodiesel. Appendix H has a complete list of the manufacturers' positions if they were available.

The first table in Appendix C summarizes the results of tensile strength testing on elastomeric materials. A loss of 25% tensile strength was deemed the acceptable limit for a conservative estimate. This may be able to be expanded, with more research, if the comments by Maxson that 40-50% property loss is acceptable are followed. The results from different studies cannot generally be directly compared because the test conditions, including biodiesel blend percentage, test temperature and exposure time, vary widely. They can however be used to gain a perspective about how the materials react to biodiesel exposure. The second table presents comments regarding the effects on various metals of exposure to biodiesel and biodiesel blends. In general, we would expect metals to exert greater effects on the fuels by catalyzing degradation reactions than the fuels would exert directly on the metals. The fuels could become corrosive once they are severely degraded (e.g., high acid number, formation of precipitates, etc.)

5.2 MATERIAL COMPATIBILITY TESTING PERFORMED IN THIS STUDY

Limited testing of three candidate fuel system elastomers was conducted in this study. Testing was ongoing at the time this report was submitted in draft, so final results are not yet available. The test protocol is described in this section, as are the materials chosen for testing and the reasoning behind their selection.

In general, we have found that diesel engine fuel systems produced since about 1993 can be expected to tolerate exposure to biodiesel blends of 20 percent and below very well. Older engines have also generally performed well on biodiesel blends, although in some cases incompatibilities have been noted between non-metallic materials in these older systems and biodiesel-blended fuels. These problems are difficult to predict without detailed, part-by-part knowledge of the classes and compositions of elastomeric parts found in specific engine models. The matter is complicated by the fact that older engines will have been refurbished and repaired, probably multiple times, over the course of their service lives. When this maintenance and repair work is done, older gaskets, seals, O-rings, etc. are replaced, usually with service parts made from current materials offering increased resistance to fuel components (and better performance generally). Thus, the fact that a generator drive, for example, is 20 or more years old does not necessarily mean biodiesel will affect its fuel system adversely. Maintenance and repairs to older diesel engine fuel systems can be expected to have been concentrated in the higher-pressure, higher-temperature portions of the fuel system, say from the fuel filter downstream. Parts operating at lower pressures and temperatures – the fuel transfer pump, the day tank plumbing, if one is used, etc. – may contain seals and gaskets made of older materials such as nitrile or even natural rubbers that will degrade and fail in long-term biodiesel fuel service.

In the course of investigating biodiesel-materials compatibility, it was learned that a study is being planned by the Coordinating Research Council. (The CRC is a collaboration of the fuel, engine and vehicle industries concerned with issues of mutual interest, such as fuel-vehicle interactions.) That program, now in progress, sought to assess the performance of five selected elastomers in soy- and rapeseed-based biodiesel blends. The materials selected, all provided by Parker-Hannifin, included two nitrile rubbers (NBRs), an hydrogenated nitrile rubber (HNBR), and two fluorocarbons (FKM). Results from this testing program, when available (expected in the second half of 2004), can be expected to expand knowledge in this area considerably. To minimize duplication of the efforts of the CRC and others, the study team identified three materials from various manufacturers and obtained 6-inch by 6-inch test slabs about two millimeters thick. Standard dumbbell-shaped test pieces were cut from these slabs and immersed in a base low-sulfur (500 ppm) diesel fuel and in a B20 made from this fuel and biodiesel obtained commercially from a currently approved fuel supplier to Miami-Dade County.

5.2.1 Material Compatibility Testing of Elastomer Specimens with Low-Sulfur Diesel and 80% Low-Sulfur Diesel Fuel/20% Biodiesel Blend

The compatibility of sealing materials with low-sulfur diesel (ULSD) and an 80% ULSD/20% biodiesel fuel blend was verified by the following American Society of Testing and Materials (ASTM) standards: D 471, "Standard Test Method for Rubber Property-Effect of Liquids" and D 412, "Standard Test Methods for Rubber Properties in Tension," as well as other relevant standards. Key steps were obtaining appropriate samples for testing, exposing them to the test environment (fuel type and temperature), measuring the effect of the test environment on the samples, and interpreting the results. According to the literature survey, the key test method is tensile strength; this governed the manufacture of test coupons and guided the overall approach.

The University of Maryland-College Park, Mechanical Engineering Department generously offered use of its facilities at no cost for testing and measurement. During the course of the experiments, several equipment failures led to lengthy delays. The fume hood, for example, experienced fan bearing failures and required over a month to repair. The MTS machine in which tensile testing was to take place had a controller failure and has not yet been repaired. Thus, quantitative values are not yet available for comparing materials properties. Qualitative comparisons are possible at this time; however, the final results of the materials compatibility testing is expected to be submitted under a separate cover as an addendum to the report.

5.2.2 Obtain Samples for Testing

After completion of the equipment survey, three materials for components such as gaskets, O-rings and fuel lines were selected for testing.

Because it had performed well in tests previously conducted by Dow Corning using rapeseed-based biodiesel blends in Europe (Maxson, et al., 2001), and because the CRC program did not include a fluorosilicone compound, we chose a Dow Corning fluorosilicone (FVMQ 28075) of 75 durometer hardness as the first test material. This material, in the form of yellow, six-inch-by-six-inch slabs, was designated Material 1.

The second material, a polytetrafluoroethylene-polypropylene (PTFE-PPE) copolymer, is produced by Seals Eastern which designates it Aflas 7182X. It is also a fluorocarbon and was supplied in the form of black six-inch-square slabs. It is Material 2.

Material 3 is a fluorocarbon (FKM) produced by Parker-Hannifin (compound V1164-75). This 75-durometer-hardness material is one of those also being tested in the CRC program mentioned earlier. It was supplied in the form of six-inch-square black slabs.

Information in the literature was deemed sufficient to predict the behavior of nitriles and hydrogenated nitriles in biodiesel exposure and elected not to duplicate any of the testing on these materials that has already been reported.

Test coupons, or samples, were prepared according to the recommended dimensions in the ASTM standard D 412. Specifically, a standard die C was used with a single impact stroke to cut uniform dumbbell-shaped samples. To the greatest extent possible, defect-free specimens were produced, although the slabs of Material 3 had some visible bubbles and other defects. This material was kept in the study since it was considered to be in a "real world" condition, as opposed to a "lab perfect" condition. A typical dumbbell is shown in Figure 1. Overall length is 5 inches. The flange portions are nominally 1.6 inches wide, while the reduced section is approximately 1.31 inches long and 0.25 inches in width.

Upon receipt, samples were checked to verify that the dimensions were correct, with particular attention to their thickness in the necked-down portion. By the testing standards, this thickness is required to be 0.08 ± 0.008 inches (see Practice D 3182). The mass was also recorded.

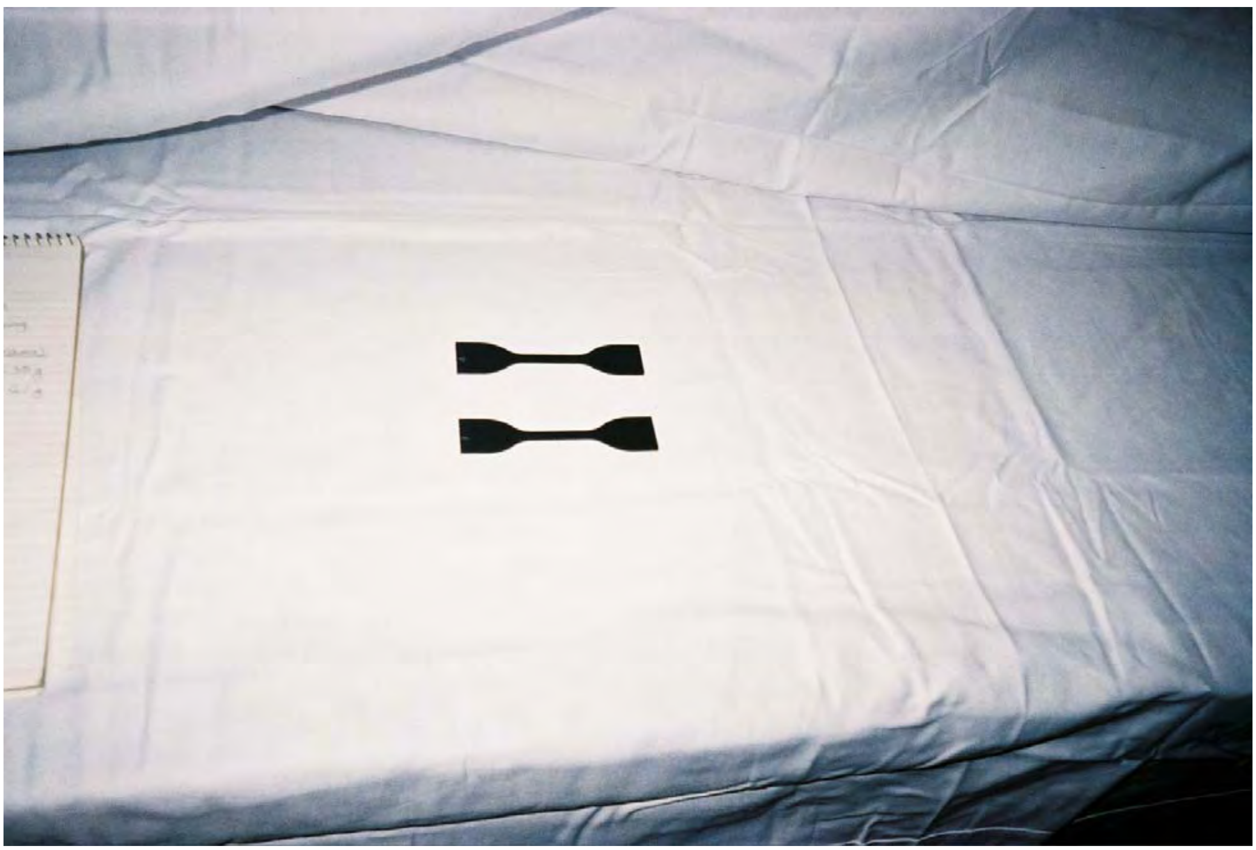


Figure 5-2. Two samples of material #3 prior to testing.

5.2.3 Exposure to Test Environment

The test environment included an equivalent of three months of exposure to two fuels, 1) low-sulfur (500 ppm sulfur) diesel, and 2) a blend of 80% low-sulfur diesel and 20% biodiesel. Since general equipment usage is on the order of 8 hours a day, 24-hour exposure to temperature and fuel for one month provided an equivalent exposure of 3 months. Samples were placed in stoppered flasks containing the fuel. The test environment was controlled for simulation of operating conditions with heat and humidity. To simulate equipment operating temperature, the flasks were heated on hot plates to 125 F (50 C). This temperature matches the recommended test temperatures in Table 1 of ASTM Standard D 471. Appropriate safety measures were followed to ensure that there was no risk of fire or other accident.

Table 1 of ASTM standard D 471 also recommends specific immersion periods. The six relevant periods for this study are 0, 22, 166, 670, 1006 and 1676 hours, which approximately corresponds to a baseline, first day, first week, first month, second month, and third month. At the end of each of these periods, the state of the flasks was examined for any visible changes and photographed. Then at least one sample (up to three if possible within budget constraints), was extracted from the flasks and prepared for measurement. Figure 5-3 presents the test setup and Figure 5-4 provides the test schedule.

Figure 5-3. Test setup on bench.

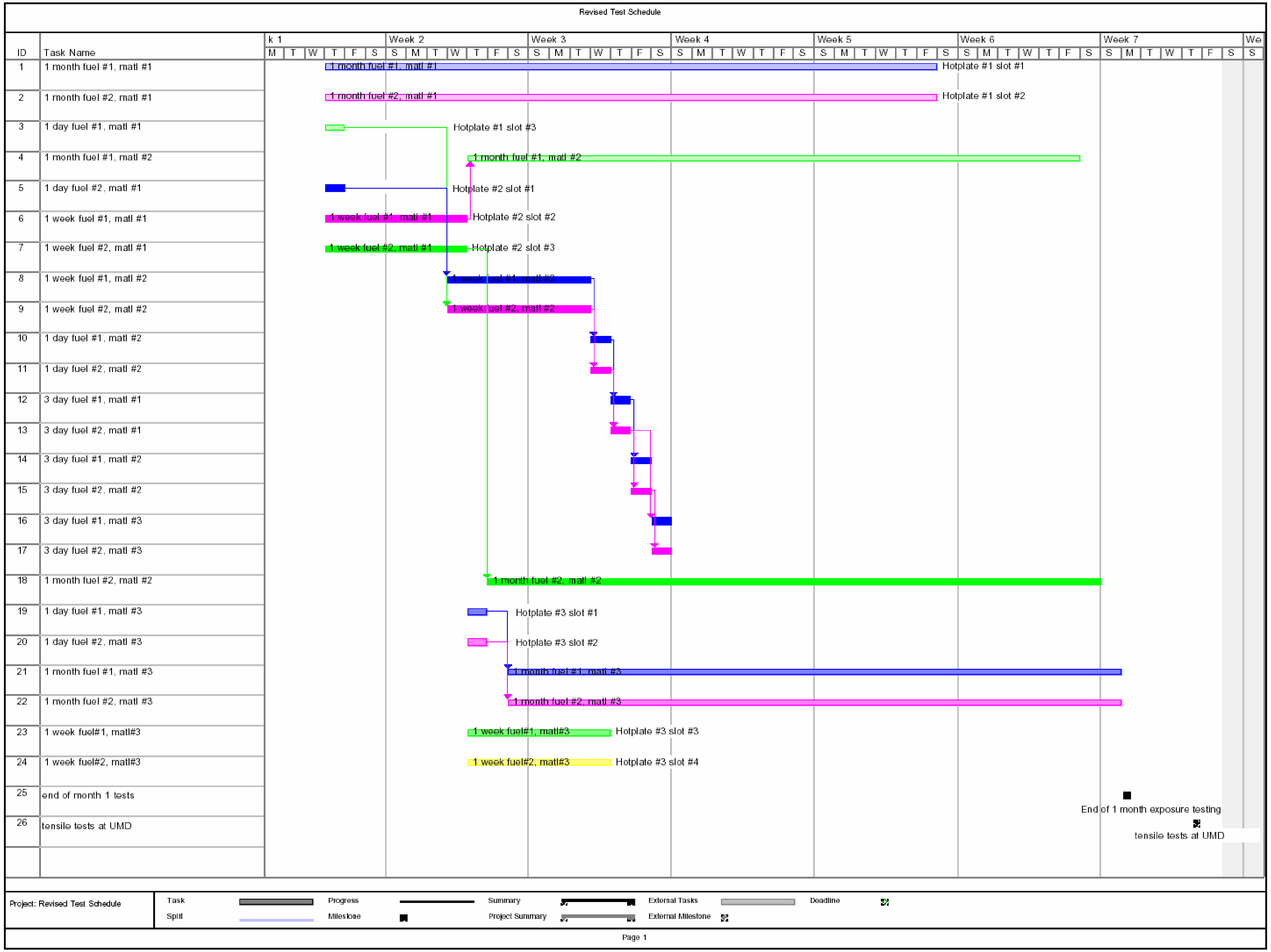


Figure 5-4. Test schedule.

5.2.4 Measuring the Effect of the Test Environment

According to the literature survey, the key test method for measuring the impact of biodiesel on engine components is tensile strength. Other tests for hardness, swell and elongation were not as useful in determining the effects of the fuels. Tensile strength is measured by engineering stress-strain curves taken at room temperature. Depending on the sample size and shape, maximum tensile strength can be measured using an MTS Uniaxial testing machine, or similar device. Figures 5-5 through 5-8 show the MTS machine and controller at the University of Maryland, College Park Mechanical Engineering Department. Ideally, it will measure tensile strength, that is, the maximum tensile stress applied in stretching the specimen to rupture.

Tensile stress, yield point, and tensile strength are based on the original cross-sectional area of a uniform cross-section of the specimen. Useful data for interpreting the results are as follows:
Nominal Thickness = 2.0 ± 0.2 mm (0.08 ± 0.008 in)
Nominal Width = 6 mm (0.25 in.)
Nominal Area = 2 mm * 6 mm = 12 mm^2

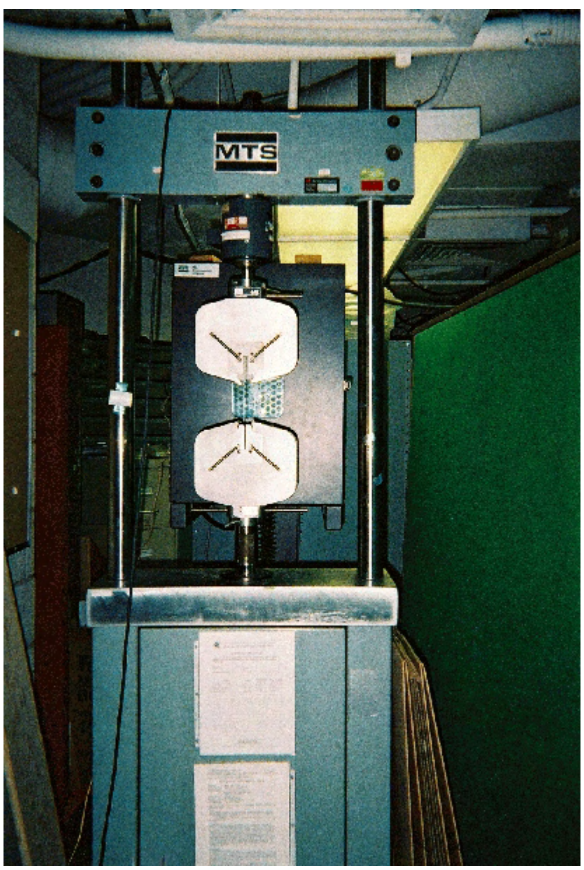


Figure 5-5. MTS machine with grips and sample.

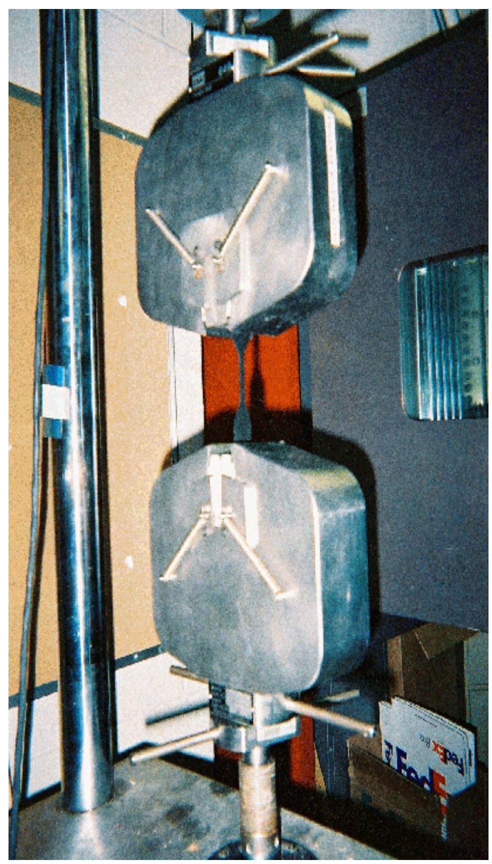


Figure 5-6. Closer view of grips and sample.

Figure 5-7. MTS control system.

Figure 5-8. Data capture computer with LabView.

A rate of elongation of 500 ± 50 mm/min (20 +/- 2 in./min) will be used, as recommended by the ASTM standards, for a distance of at least 101.6 mm (4 in.), which is the limit of the test machine ram. To implement this, the controller will be programmed to operate in Displacement Control mode. Special grips hold the specimens in place. These grips have a spring and slide mechanism that maintains a strong hold on the specimen, even as forces increase. In the initial setup and checkout of the MTS machine, lines were marked on the sample at the edge of the upper and lower jaws. After a test run, the lines were observed to make sure that the sample had not moved. In addition, techniques were developed to ensure that samples were consistently gripped across the widest portion of the flange and that it was held in a vertical position.

Test coupons were cooled to room temperature prior to tensile testing. Mass and thickness were measured to determine if any swelling had occurred. Typical results are given in Figure 5-9 below. If a specific sample and fuel combination exhibits a significantly lower-than-expected tensile strength in two separate test periods, the sample will be deemed incompatible with the fuel, and tensile strength measurements will be discontinued.

5.2.5 Interpretation of the Results

At this stage, qualitative results are available, and are shown in Figures 5-10 through 5-13. These figures show that there was essentially no change in color from the unexposed to the 1-day and 1-week exposures of all fuels and all materials. Also, no surface damage was visible. Thus, the preliminary results show no adverse results from the use of low-sulfur diesel or biodiesel blend.

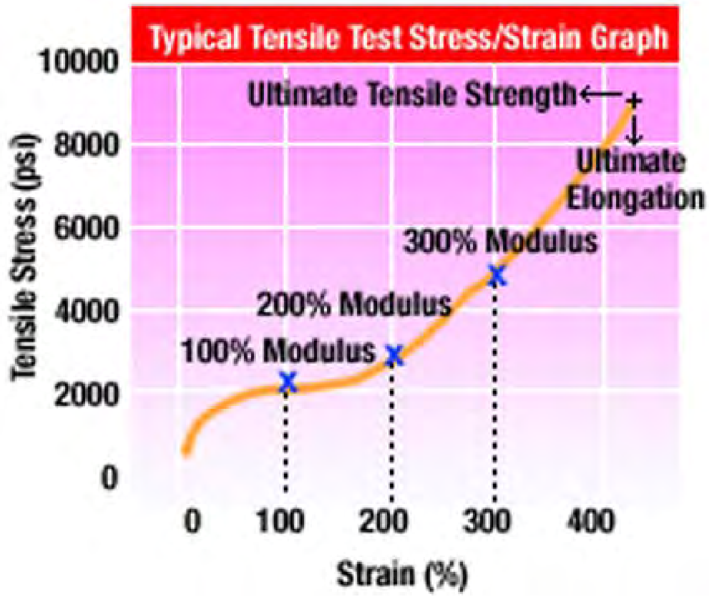


Figure 5-9. Typical output of tensile test for an elastomer (courtesy of AirProducts).

Figure 5-10. Material #2 post-testing. Low-sulfur diesel on the right, blend with biodiesel on the left.

Figure 5-11. Post testing for material #1. An unexposed sample is at the top for comparison.

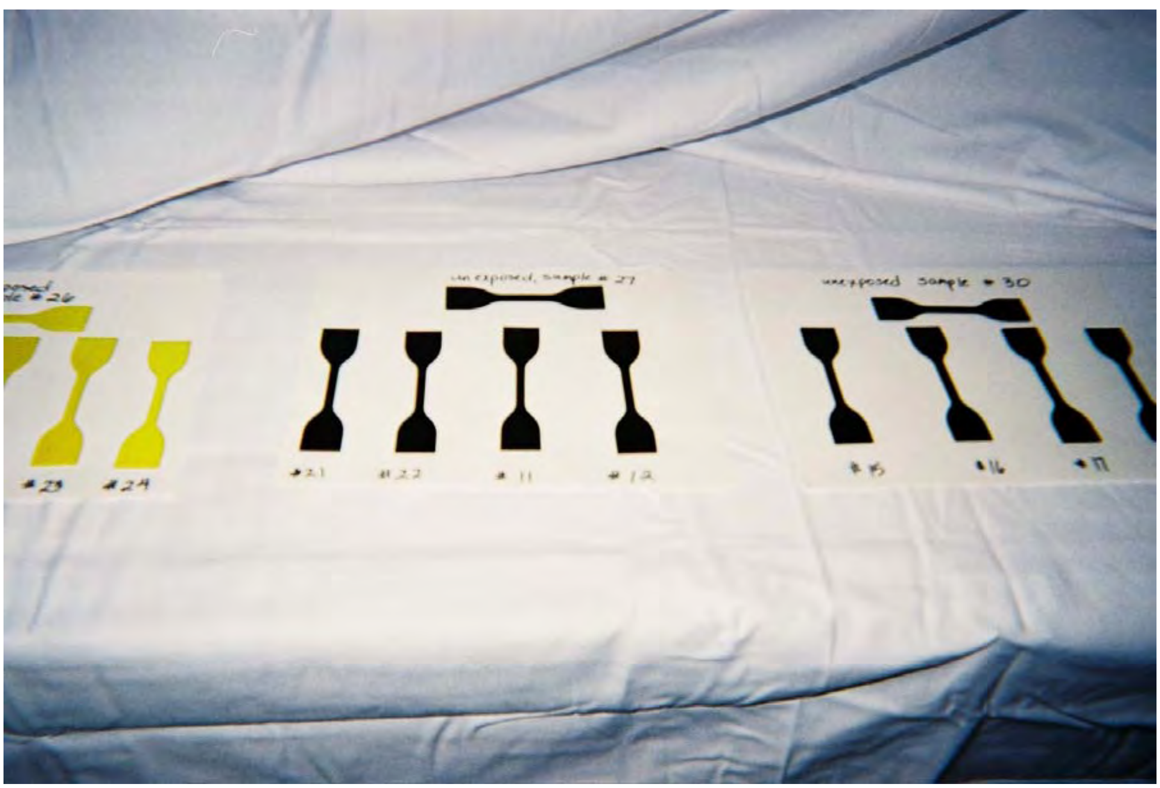


Figure 5-12. Post -testing for material #2. An unexposed sample is at the top for comparison.

Figure 5-13. Post-Testing for Material #3. An unexposed sample is at the top for comparison.

At the completion of testing, measurements and conclusions will be produced and included in the final report. Data from literature will be compared with results of this test series as a quality check in all cases where such data is available.

5.3 POTENTIAL MDAD EQUIPMENT APPLICATIONS AND NECESSARY MODIFICATIONS

As described in the previous section discussing the materials compatibility, one of the major potential problems with using biodiesel is the degradation of elastomeric materials such as hoses, seals, gaskets, and adhesives that were not designed for use with biodiesel. According to *Biodiesel Handling and Use Guidelines* published by NREL in 2001 (14), older engines, especially those manufactured before 1993, may still use nitrile rubber which is prone to degradation when exposed to biodiesel. Engines made in 1994 and after generally use biodiesel-resistant materials. Several long-term tests (4, 7) have backed up this study, showing problems with engines made in 1991. Several papers discussed engine teardowns by the manufacturer following long-term (over 100,000 miles) biodiesel use (B50 and B100) and showed normal engine wear (4, 7). This suggests that the potential problems of using biodiesel are limited to the fuel system. NREL updated the *Biodiesel Handling and Use Guidelines* in 2003 and stated that several million miles of user data has shown that engines dating back to 1980 have experienced few material compatibility problems while using B20.

A conservative implementation approach is suggested for MDAD initially to allow the maintenance staff and managers to gain experience with the fuel and its behavior. The majority of the literature sources have shown that newer engines will have the fewest potential problems, their fuel systems generally using materials that are compatible with biodiesel.

Biodiesel, in common with all other fuels, has a storage life, which varies with storage conditions and fuel makeup. Engine and fuel injection equipment manufacturers regard biodiesel as unsuitable for storage longer than six-months, and ASTM D 6571 reinforces this. With stability enhancing and anti-microbial additive packages, it may be possible to increase the safe storage period. Biodiesel storage issues will be discussed in detail in Section 6. The biodiesel implementation plan which will be laid out in Section 7 will allow the necessary experience to be accumulated and confidence with the fuel to be gained.

5.4 POTENTIAL MDAD EQUIPMENT PERFORMANCE ON BIODIESEL

In general, the difference in performance between a vehicle running on diesel fuel and a B20 blend should be nearly imperceptible. Neat biodiesel has a lower energy content than diesel, by about 9 percent on a volume (per-gallon) basis. However, a gallon of B20 blend contains only about1.5% less energy than a gallon of petroleum diesel fuel. Additionally, biodiesel usually has a higher cetane number than typical diesel fuels. The resulting cetane increase of a biodiesel blend can allow improved engine cold starting and help reduce emissions.

Several studies encountered during the elastomeric material compatibility research also had results for engine teardowns conducted by Cummins and Caterpillar. These showed engine wear similar to engines running on diesel fuel (4, 7). This provides evidence that there are no long-term maintenance issues caused by running on-spec biodiesel fuel. Biodiesel is a highly effective lubricity additive. As little as 2 to 3 volume percent can double the lubricity of a base diesel fuel, as measured by the Scuffing Load Ball-on-Cylinder Lubricant Evaluator (SLBOCLE). As diesel fuels are desulfurized more and more severely, ultimately to 15 parts per million sulfur under current and future EPA regulations, fuel lubricity may become an issue. Biodiesel can provide a relatively low-cost solution to problems encountered as a result of declining lubricity.

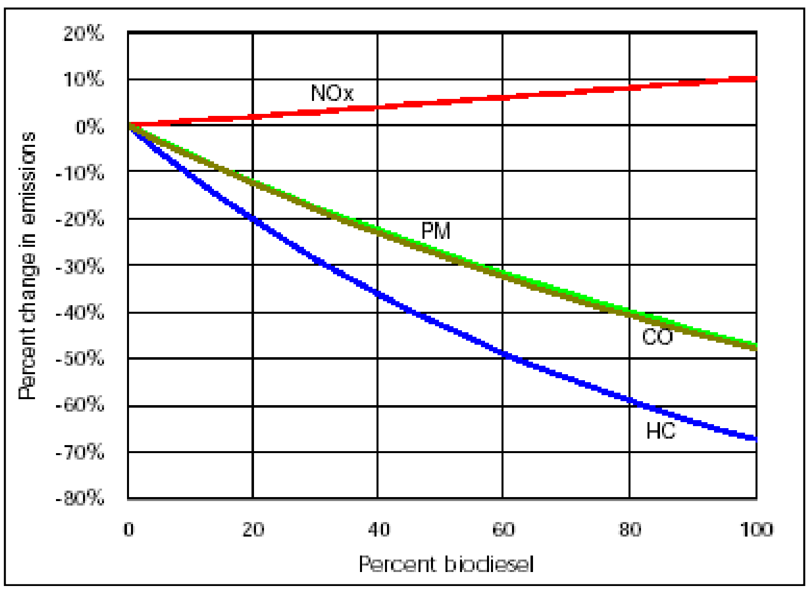


Figure 5-14. Emissions reduction performance of biodiesel in a heavy-duty diesel engine (Source: EPA).

The EPA performed a comprehensive study on the impacts of biodiesel on heavy-duty diesel engine emissions (15). There are many factors related to the fuel feedstock used to produce the fuel that affect the emissions and engine performance. However, the average generic emissions performance is summarized in Figure 5-14 taken from this report. The report cautions that the results pertain only to heavy-duty diesel engines since the study contained mainly results from this type of engine. A B20 blend can decrease the volatile organic compound emissions (shown as HC (hydrocarbon)) by 21%. Particulate matter (PM) is reduced by 12%, and CO by 13%. The NOx emissions increase due to the fuel-borne oxygen, however in B20 blends, this is only by 1-2% on average. These trends continue for B100 with VOCs reduced by 67%, PM by 47%, CO by 48%, and NOx increasing by 10%.

5.5 IMPACTS ON MAINTENANCE

Biodiesel has solvency properties, and the higher the blend, the stronger this effect. Biodiesel or biodiesel blends put into fuel tanks will loosen existing deposits of fuel breakdown products (known as asphaltenes) from the tank and downstream lines and equipment. In the long term this is a benefit, in the short term it can cause problems if steps are not taken to ensure the loosened material does not reach injection equipment, or plug the fuel filter. A related and potentially even more severe problem may occur if the deposit-dissolving action of the biodiesel fuel also frees hard, abrasive particles such as fine rust to travel downstream toward the engine. For these reasons, the recommended practice is to replace the fuel filter within the first month of switching to B20, and sooner if switching to B100 because of its higher solvency. There is no definite rule to follow for determining how long to wait to change the fuel filter. Also, depending on how old the engine is and how many miles, or hours, are on it, more than one fuel filter replacement may be required after switching to biodiesel to catch and remove all of the loosened particles. As a minimum, two additional fuel filter replacements are recommended for each vehicle once it is switched to biodiesel, the first being put in when the vehicle is first filled with biodiesel. This may be too cautious, but a little more effort on the initial time using biodiesel can save big problems from occurring later on. Caterpillar has begun recommending 2-micron fuel filters for its on-road engines to combat wear damage to high-pressure fuel injectors, similar to problems seen earlier in high-pressure hydraulic equipment. Other engine builders may follow suit. While these problems are not expected to be as acute with older, lower-pressure diesel fuel injection systems, the additional protection afforded by using a 2-micron filter rather than the typical 10-to-15-micron filter is added inexpensive insurance.

Biodiesel (B100) is also prone to absorb significantly more water; up to 1500 parts per million - than petroleum distillate fuels. Diesel fuel may dissolve around 125 ppm of water at normal temperatures. During production, biodiesel undergoes several water washings to remove unreacted methanol, residual catalyst (usually a strong caustic such as lye), glycerine, etc. As a matter of production quality control, wash water left dissolved in the biodiesel must be substantially removed before the product is distributed. Thereafter, biodiesel will tend to re-absorb water from “bottoms” in tanks and other parts of the distribution system. Other things being equal, using any biodiesel fuel may tend to increase the net rate at which water enters a fleet’s fuel system. Water is not generally problematic while it is dissolved in the fuel, which will usually remain clear and bright. However, the solubility of water in distillate fuels like diesel is strongly influenced by temperature. As stored fuel cools, excess dissolved water will tend to coalesce into very small droplets, giving the fuel a cloudy or hazy appearance. When droplets have coalesced and grown to a critical size, they will begin to drop out of suspension in the fuel and form bulk water deposits at the bottom of the tank. In this separated form, water is potentially damaging to equipment. It can be corrosive, a condition that will be aggravated if microorganisms begin growing in the water, increasing its acidity. Microbial activity will also produce clumps and mats of material that will clog fuel filters. Water is a poor lubricant and can cause scuffing and seizure of closely fitted metal parts such as fuel injection equipment. For these reasons, water-coalescing fuel filters are recommended for engines burning biodiesel fuel. Inspecting these filters regularly will provide advance warning if water is accumulating in tankage (by whatever means) and prevent it reaching the most vulnerable parts of the engine fuel system.

There are no other maintenance impacts. Studies have shown that the lube oil dilution rate is similar to traditional diesel fuel.

5.6 COST IMPACTS – VEHICLE MODIFICATIONS, FUEL, MAINTENANCE, OPERATIONAL

5.6.1 Vehicle Modifications

Vehicles requiring fuel system modifications are excluded from the three initial rounds of implementation. However it is possible to retrofit vehicles in this category if the effort is deemed necessary. All vehicles switching to biodiesel will require new fuel filters, so those costs will be discussed in the “Vehicle Maintenance” section below. Parts requiring replacement will include rubber fuel lines at points along the line where metal lines are not used, fuel-wetted O-rings, gaskets and sealants. The cost for fuel lines depends on how much of the run uses rubber hoses, rather than metal tube. The labor for changing fuel lines on a light-duty vehicle is approximately double due to the restricted areas and longer fuel line run. The total estimated cost for installing new fuel lines ranges between $300 and $450 depending on the vehicle and engine type.

5.6.2 Fuel Cost

Biodiesel cost depends on the tax situation of the client and the amount purchased at a time. Discounts are given if a delivery is 7,500 gallons or more. Typically, the per-gallon cost premium of a biodiesel blend above diesel is roughly one penny per percent of biodiesel (e.g., B20 would be approximately 20 cents per gallon more than diesel. Figure 5-15 shows historical biodiesel prices in Miami since April 2003, with the ex tax price of No. 2 diesel fuel shown for comparison.

5.6.3 Vehicle Maintenance

The fuel filter should be replaced when the vehicle is switched over to any biodiesel blend, and should be replaced twice in the first month or so. This is more frequent than typical, and will be an additional cost. Estimating the fuel filter cost of $20 and ¼ hour of labor at $50/hour equates to an extra $32.50-$45 in maintenance costs per vehicle. Coalescing filters with transparent

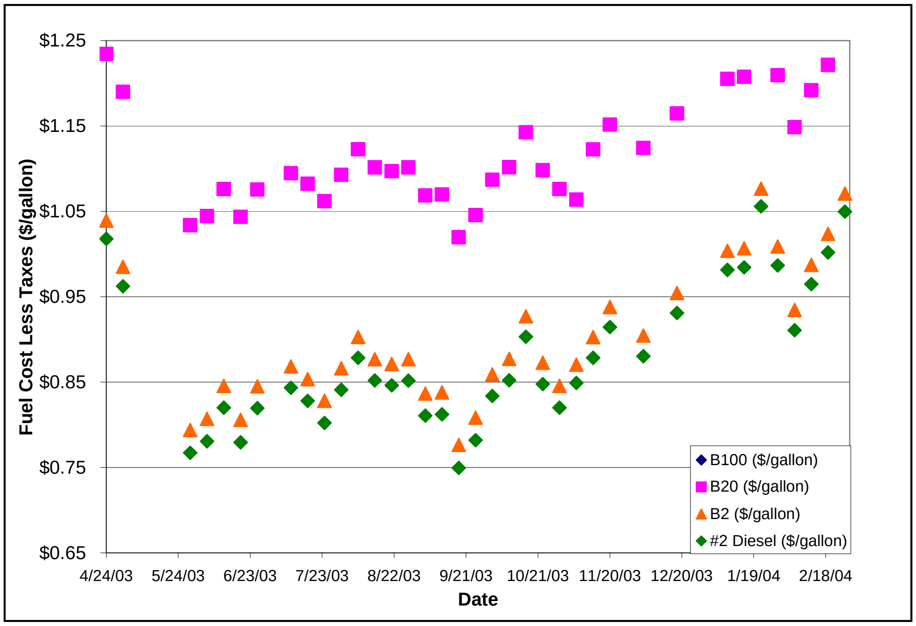


Figure 5-15. Historical Miami biodiesel prices (pre-tax). The price for B100 was steady at $2.10 over the entire period (Source: Alternative Fuels Pricing Index).

sediment bowls are recommended to ensure that free water is separated from fuel delivered to the engine and to facilitate visual monitoring of fuel condition.

By putting a priority on ensuring good fuel filtration and switching the fuel filters out frequently in the first couple months will help ensure that asphaltene sludge and rust particles loosened by the biodiesel will not cause problems downstream of the fuel filters. If this is not done, the fuel injectors could be permanently damaged, requiring their replacement. As an example, the parts cost for fuel injectors for light-duty diesel pickup models in the MDAD vehicle inventory ranges from $50 - $350 depending on the vehicle model. The additional cost of replacing a single fuel injector will more than offset the cost of conscientious fuel filter replacements in the first couple months.

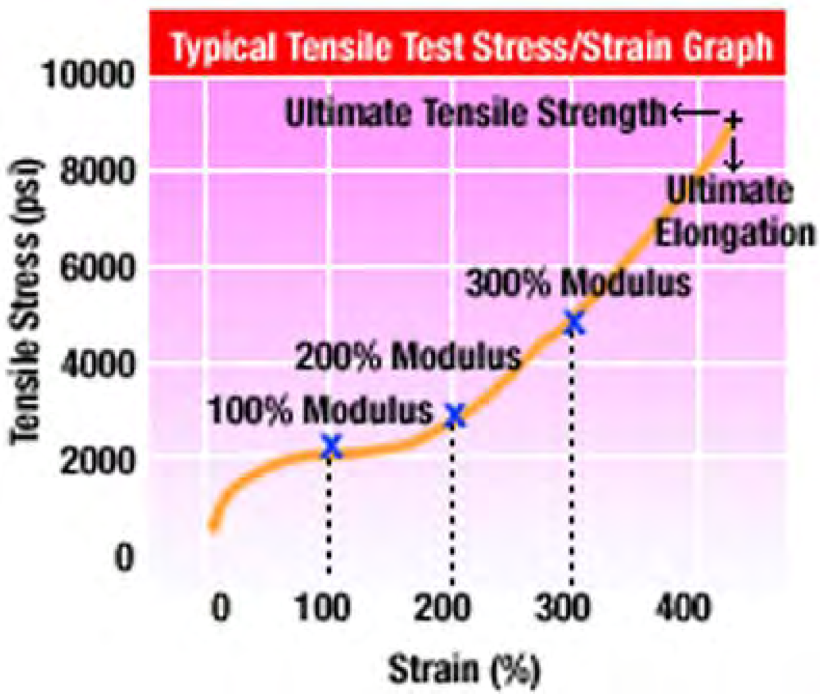


Figure 5-9. Typical output of tensile test for an elastomer (courtesy of AirProducts).

6. BIODIESEL STORAGE REQUIREMENTS FOR MDAD EQUIPMENT

One of the benefits of biodiesel blend use is the fuel can generally be stored in existing diesel storage tanks without significant modification. This keeps capital costs low for fleets converting to the fuel. However, the higher solvency of biodiesel blends requires certain tank maintenance procedures and upgrades to existing storage tanks to ensure engine operating reliability. The following section discusses the changes necessary for the airside diesel tank population for refueling MDAD equipment with biodiesel blends.

6.1 EXISTING DIESEL STORAGE TANK POPULATION SERVING MDAD AIRSIDE OPERATIONS

Currently, MDAD's airside equipment fuel needs are served by two separate locations: the Location O and 20th Street fuel depots, respectively. Location O has 12,000-gallon and 4,000-gallon underground diesel tanks as well as a 12,000-gallon underground gasoline tank. It currently refuels the MDAD gasoline-fueled baggage tugs and gasoline and diesel lawn mowing equipment. The AFMP prescribed the replacement of the gasoline baggage tugs with diesel hybrid electric versions[1]. Although the diesel fuel tank exists at Location O, it primarily serves MIA tenant equipment in addition to MDAD equipment and therefore cannot be utilized for biodiesel. However, it may be possible for this tank to be converted at some time in the future to biodiesel if tenant organizations decide to convert their equipment. A new, underground diesel storage tank with dispenser will be needed at Location O to serve MDAD's future diesel hybrid electric baggage tugs and mowing equipment. This tank installation will include a concrete pad and single hose dispensing system.

The landside location currently employing diesel fuel storage is the 20th Street fuel facility. This location incorporates one 10,000- gallon aboveground diesel tank and two 10,000-gallon aboveground gasoline tanks. These tanks serve the remainder of MDAD's airside vehicles including maintenance pickups and heavy trucks, tractors and mowing equipment. They also serve a significant portion of airport tenant operations and so it too cannot be directly converted to biodiesel. Instead, additional biodiesel storage tank capacity will be necessary for fueling MDAD equipment. Installation should be facilitated at the 20th Street location by the existence of an empty concrete pad established to provide future fuel storage needs when necessary.

The remainder of the MDAD diesel storage tank inventory consists of various day tanks and smaller tanks for serving standby power generators and fire pumps. These tanks typically range in size from 100 to 2,000 gallons. This equipment operates on high-sulfur (5,000 ppm) non-road diesel fuel rather than low-sulfur (500 ppm) diesel fuel. These tanks are refilled every six months via tank truck deliveries from outside fuel suppliers unless the generators or fire pumps are used for extended periods of time during power outages or training exercises.

[1] These tugs are principally electric battery-powered with a small, diesel genset to provide additional range.

6.2 USE OF EXISTING TANKS FOR BIODIESEL STORAGE

B20 blends can be stored in and dispensed from the same refueling equipment currently used for conventional diesel fuel. Low-concentration biodiesel blends like B20 have been shown to be compatible with most refueling tank and dispensing system materials. If existing diesel tanks are used, they should be cleaned and de-watered before the first fill of B20, and may need to be cleaned within two- to four-weeks of initial use to remove any tank sludge and residue that B20 may have loosened from the walls of the tank. This applies to all sizes of storage tanks including generator day tanks. Biodiesel (B100) is a potent solvent and in fact is sold under various trade names as an industrial solvent. It will rapidly remove deposits (generally called asphaltenes) left by petroleum fuels. Low-level blends like B20 are less prone to do this and the solvent cleaning action they exert will be slower. For this reason, dispenser filters should be replaced at the time tanks are purged, since they will have collected the residues from the tank and lines. Loosening of pre-existing deposits may also mobilize fine, abrasive particles such as rust. It is especially important that this material be intercepted as soon as possible by a filter of some type, as it can be particularly damaging to diesel engine fuel systems.

Biodiesel (B100) can dissolve more water (over 1,000 parts per million) than familiar petroleum distillates like diesel fuel. At typical atmospheric temperatures, diesel fuel may dissolve only 100 to 125 ppm of water. Biodiesel is also hygroscopic, able to attract and absorb moisture (humidity) directly from the air. These characteristics will be greatly moderated in a low-level biodiesel blend such as B20. Nevertheless, a blend will have a greater propensity to absorb moisture from daily tank “breathing” than conventional all-petroleum diesel fuel. In aboveground tanks such as used at MIA, this is of more concern than with underground tanks. Aboveground tanks are exposed to ambient conditions and experience wider temperature swings. As the fuel in the tank warms, it expands, forcing air from the tank. As the fuel cools and contracts, it draws air (and water vapor) into the tank. Biodiesel fuels will absorb more moisture from this daily inflow of fresh outside air, especially in the higher-temperature and humidity environment of South Florida.

Biodiesel fuels will also absorb water from contact with tank water “bottoms.” It may also be possible in some circumstances for biodiesel fuels to contribute to these deposits of free water. The ability of a petroleum fuel to retain dissolved water depends strongly on temperature. As the fuel is cooled, dissolved water can begin to come out of solution in the fuel and agglomerate into microscopic fuel droplets. These will give the fuel a cloudy or hazy appearance. Suspended water droplets will coalesce and grow with time and upon reaching some critical size will fall by gravity to the bottom of the tank, creating or adding to bottoms. A B20 blend made from B100 at or near its water saturation point may have a dissolved water content greater than the blend fuel can hold as its temperature falls. Water forced from such a blend by falling temperatures will add to tank bottoms. Water bottoms also support and encourage biological growth in the tank. This can severely compromise fuel quality, increase the corrosivity of water bottoms, plug fuel filters and cause other operating problems. Routine removal of water bottoms and fuel residues therefore becomes important if existing storage tanks are to be used for biodiesel fuels.

Petroleum tank cleaning in preparation for B20 storage is not unlike that used for other fuels. The process depends on the size of the tank, its previous petroleum product contents, and the amount of residue to be removed. First, existing tank bottoms are vacuumed out and collected for disposal. A technician would enter larger tanks and begin the cleaning. Smaller tanks can be cleaned by hand. Waste residues and bottoms remaining from the cleaning process are removed and collected for disposal. Typical rates were obtained from a local vendor for cleaning 2,000-gallon tanks. A minimum site time of three hours was quoted for three technicians (OSHA requirement). The estimate included removal of existing fuel from the tank, entry of a technician into the tank and vacuuming residue into a vacuum truck. Disposal of any waste fuel (sludge) or contaminated water would be additional. Cleaning three 2,000-gallon tanks closely spaced (no requirement to relocate the vacuum truck or other equipment), would cost approximately $3,000, plus any disposal fees.

After cleaning, tanks should be inspected internally and piping, or valves, repaired or upgraded as necessary. At this time, potentially problematic elastomers in the piping should be upgraded for biodiesel use. For low-level blends like B20, few materials issues in the piping should be expected. However, original tank vendors should be contacted to review materials and their compatibility with biodiesel in older tanks. To reduce the amount of moisture drawn into the tank by daily "breathing," a vent pipe desiccant filter (e.g., brand name Air Sentry) should be installed, especially for aboveground tanks.

Existing diesel fuel dispensers can be reused for biodiesel with some minor modifications. Original filters should be changed out before biodiesel dispensing begins. Although dispenser materials will generally not be an issue, original dispenser equipment manufacturers should be contacted to discuss reuse of the equipment with biodiesel, especially in the case of older equipment. Because B20 is a mild solvent, initial use will result in the removal of remaining deposits and residues in the fuel tank, pipelines, and even the dispenser. These residues will then pass to the dispenser's filtration system. After several weeks of use, these filters should be inspected for replacement.

6.3 NEW STORAGE TANK REQUIREMENTS FOR BIODIESEL

If needed, new aboveground storage tanks and dispensers can be installed for storing biodiesel products, pending security and engineering approval. These tanks are identical to those used for conventional diesel fuel and meet all current EPA regulations for storage tanks. The costs of installing B20 fueling facilities are outlined in Table 6-1 for B20 tank sizes of 250, 500 and 10,000 gallons. These generic costs include installation of the storage tank and a new pump and dispenser. The aboveground tank has a side-mounted dispenser and requires no product piping. The cost estimate for the aboveground tank also includes equipment for ground-level fill and the special fill box to prevent any fuel spilled during tank filling from getting into the groundwater.

TABLE 6-1. COST OF STORAGE AND DISPENSING FACILITIES FOR DIESEL BLENDS

Cost Component	250 gallon Aboveground Tank	500 gallon Aboveground Tank	10,000 gallon Aboveground Tank
Total materials	$8,950	$9,600	$44,100
Total labor	$500	$600	$11,000
Total materials & labor	$9,450	$10,200	$55,100

If a new tank is required, the vendor should be informed and asked to guarantee that all components in contact with the B20 fuel comply with NREL/TP-580-3004, *Biodiesel Handling and Use Guidelines*, September 2001.

6.4 BIODIESEL FUEL SAFETY AND TANK MAINTENANCE

The fire safety characteristics of a biodiesel blend like B20 are similar to those of conventional diesel fuel. An example Materials Safety Data Sheet for biodiesel is provided in Appendix E. Biodiesel (B100) is considerably less volatile than No. 2 diesel fuel. Its flash point is specified (ASTM D 6751) to be 130^{o}C, minimum, compared to the minimum value of 52^{o}C specified (ASTM D 975) for No. 2 low-sulfur diesel fuel. A B20 is thus apt to have a higher flash point than the base diesel fuel from which it's made and to be marginally safer to handle.

A biodiesel blend fire should be fought as a petroleum diesel fire. Extinguishing media include dry chemical, foam, Halon, water spray (fog). Firefighters should use self-contained breathing apparatus (SCBA) to avoid exposure to smoke and vapor. Biodiesel-soaked rags can ignite spontaneously as the biodiesel oxidizes. They should be kept in a sealed metal container and washed with soap and water and dried in a well-ventilated area before disposal or re-use.

Pure biodiesel contains no hazardous materials. It can be stored in well-ventilated locations with other fuels at temperatures from 50 to 120 degrees F. Biodiesel is nontoxic, but inhalation of fumes is discouraged, as are ingestion and contact with the eyes and skin, as discomfort and irritation may result. Biodiesel may also attack some painted finishes and the outside rubber layers of some fuel hose.

No significant maintenance is required for biodiesel tank storage. As mentioned, dispenser filter changeout will likely be necessary for existing diesel tank systems early in the conversion process to biodiesel, and it may be advisable to opt for the finest available filters during this period, to ensure that small, potentially damaging abrasive particles are captured. After the introductory period, filter maintenance should be the same as for conventional diesel fuel. The most significant maintenance issue with biodiesel storage is long-term stability. As Section 3 of this report mentioned, long-term degradation of biodiesel fuel quality by oxidation and other chemical reactions is possible, and may be more rapid in the warm climate of South Florida. Microbial growth in storage tanks is expected in the local climate and by the ready biodegradability of biodiesel. Microbicidal treatment of the first tank fill of biodiesel blend should be effective in limiting biological growth; thereafter, regular tracking and removal of water bottoms will keep biological populations suppressed. If these fuels are to be stored for long over three months, it is recommended that regular (monthly) fuel samples be taken to monitor product stability. Measurements of acid number may be sufficient to monitor the condition of B100. Gauging the condition of B20 in storage is not as straightforward. Visual inspection of full-depth tank samples can help identify early fuel color changes and any deposition of insoluble fuel breakdown products.

7. BIODIESEL IMPLEMENTATION AND RECOMMENDATIONS

This section presents a phased implementation schedule for biodiesel fuel utilization within the MDAD airside diesel equipment inventory. As presented below, the implementation schedule was developed based on the analyses previously discussed in this study. Several phases of biodiesel implementation are presented based on the suitability of the equipment for biodiesel use and the overall experience gained by MDAD personnel over the phase-in period. The ultimate VOC emissions reductions and petroleum fuel savings from the projected biodiesel use are also addressed in light of the 2010 airport-wide goals. Finally, measures of cost-effectiveness are offered for comparing the benefits of the various biodiesel phase-in scenarios.

7.1 BIODIESEL IMPLEMENTATION DEVELOPMENT

7.1.1 Assumptions

In developing a biodiesel implementation scenario for MDAD airside operations, a number of basic assumptions were necessary. These included the following:

- The baseline (2003) composition and numbers of the MDAD airside equipment inventory were assumed to remain constant over the period 2004 through 2010.
- Future equipment/vehicle turnover rates (except for medium- and heavy-duty vehicles, generators and fire pumps) were assumed to be 10-year, 100,000-mile based on discussions with key personnel. Based on an analysis of the current inventory, no future turnover of the medium- and heavy-duty vehicles, generators, or fire pumps was assumed. However, based on their high annual mileages, the medium- and heavy-duty vehicle engines were assumed to be rebuilt every 10 years.
- Replacement equipment was also assumed to have a 10-year, 100,000-mile useful lifetime within the MDAD inventory. Newly installed biodiesel refueling/maintenance infrastructure was assumed to have a 20-year useful lifetime.
- Projected use of biodiesel by MDAD equipment was in the form of B20 blends. No blends of higher concentration were assumed to be used at MIA due to possible fuel system material issues, as illustrated in Section 5 of this report.
- Based on the materials compatibility analysis presented earlier (Section 5) in this document, equipment older than model year 1996 was not included in the biodiesel implementation due to suspected materials compatibility issues.
- Baseline MDAD equipment was replaced with comparable, new, diesel-fueled equipment at the completion of its assumed useful life.
- Baseline MDAD equipment usage rates (annual mileage, hours of use, etc.) were assumed to remain constant over the period 2004 to 2010.
- Vehicle fuel economy estimates were taken from U.S. Department of Energy's www.fueleconomy.gov website database and are the city fuel economy values.
- The fuel economies and fuel usage rates of baseline equipment not requiring replacement over the years 2004 through 2010 were assumed to remain constant over that time period.

- The fuel economies and fuel usage rates of newly acquired equipment were assumed to remain constant through year 2010.
- The emissions performance of baseline diesel airside vehicles not requiring replacement over the years 2003 through 2010 was estimated using the EPA MOBILE6 model for on-road vehicles for that time period. In general, MOBILE6 projects deteriorating emissions performance for these vehicles as mileage accrues. Emissions from non-road equipment were estimated using EPA's Non-Road Emissions Model or AP-42 emission factors.
- Specific equipment category information (e.g., fuel tank volume) was estimated from typical values of representative equipment models.
- Overall, vehicles with fuel tank turnover rates less frequent than four months were excluded from consideration of biodiesel fueling due to potential fuel stability issues.

7.1.2 Biodiesel Applicability Guidelines

In developing various scenarios for biodiesel application within the MDAD inventory, several technical guidelines based on previous analysis in this study were used, including the following:

- *Materials Compatibility* – Certain elastomer materials found in seals, hoses, gaskets, O-rings and fuel lines are susceptible to accelerated degradation when in contact with biodiesel. These materials were identified through the literature review and by additional testing of fuel system elastomers (see Section 5). It was determined that equipment/vehicles manufactured in the 1996 model year or after are unlikely to exhibit engine fuel system problems and were deemed acceptable for biodiesel usage. MDAD equipment/vehicles manufactured prior to 1996 would either have to have received biodiesel-compatible fuel system materials through normal replacements and engine rebuilds, or be replaced by new diesel equipment/vehicles suitable for use with biodiesel fuel through normal end-of-lifecycle attrition.
- *Fuel Stability and Storage* – As noted in Section 3 above, biodiesel tends to be less resistant to oxidative and thermal deterioration than most conventional diesel fuels, which also undergo these chemical and physical changes. This, combined with biodiesel's well-known biodegradability (susceptibility to breakdown by microorganisms), makes biodiesel less suitable for long-term storage. These tendencies of biodiesel (B100) are moderated significantly in B20 blends, but they are not eliminated. Long-term storage in this context means storage for more than six months, taking into account the duration from actual fuel production, through storage on-site at MIA, though storage in the vehicle or engine tank, until its consumption by the engine.
- *Fuel Usage* – Equipment and vehicle annual usage rates and mileages were guiding principles in selecting the most advantageous biodiesel applications in the MDAD airside fleet. Low usage and mileage were less attractive due to cost efficiency and long-term fuel storage considerations. As shown below, equipment/vehicle fuel tank storage duration helped determine biodiesel implementation schedules under various usage scenarios. A conservative maximum allowable duration for onboard storage of four months was assumed for purposes of implementation. In keeping with the overall six month long-term storage guideline mentioned above, this allows a two-month period

from fuel production, through on-site storage at MIA, to being dispensed to MDAD equipment. Longer onboard storage durations may be feasible once MDAD gains some experience and confidence in B20 blend stability through a dedicated fuel sampling and testing program.

- *Costs* – Incremental fuel costs for B20 blends are approximately $0.25/gallon. All vehicles will require one or two additional fuel filter replacements, which is an additional $35 - $45 per vehicle. Equipment/vehicles from before 1996 that require replacement of the fuel-wetted elastomeric parts will cost an estimated $300 - $500 in parts and labor. This cost may not be easily absorbed by MDAD; including such equipment in a biodiesel fuel use program may require waiting until it is replaced with newer equipment.

7.2 MDAD AIRSIDE INVENTORY REPLACEMENT AND REBUILD SCHEDULE

Discussions were held with key MDAD fleet personnel to determine average equipment useful lifetimes and turnover rates. Through these discussions it was determined that most of the airside equipment categories except the medium and heavy trucks, standby generators and fire pumps are maintained according to a 10-year, 100,000 mile lifetime. The medium and heavy trucks, standby generators and fire pumps are held to longer lifetimes, in some cases over 30 years. Thus, for these MDAD airside categories, no replacements were assumed for years 2004 through 2010. However, it was assumed that the diesel engines powering this equipment would be rebuilt on continuous, 10-year cycles.

Table 7-1 presents a projected MDAD baseline equipment replacement and rebuild schedule for years 2004 to 2010. The figures under each category pertain to the numbers of units in a given year which come up for replacement under the equipment lifetime guidelines described above. This equipment turnover schedule served as the basis for development of the future biodiesel implementation scenarios described later in this section. That is, the retirement of old diesel equipment and its replacement with new versions, and the rebuild of old engines with biodiesel-compatible components, allows greater use of biodiesel in the future.

Table 7-1. Baseline Equipment Replacement/Rebuild Schedule by MDAD Fleet Category

CY	Pickup (Full-Size)	Truck (MD-HD)	Truck (Maint.)	Van	Tractor & Mower	Baggage Tugs	Gener-ators	Fire Pumps	Annual Totals
2004	3	4	0	0	3	7	0	0	17
2005	3	5	0	0	0	3	0	0	11
2006	3	3	3	0	1	0	0	0	10
2007	2	3	2	0	0	2	0	0	9
2008	0	3	3	0	0	0	0	0	6
2009	1	1	3	1	0	0	0	0	6
2010	4	4	3	0	0	0	0	0	11
Total	16	23	14	1	4	12	0	0	70

7.3 BIODIESEL IMPLEMENTATION SCENARIOS

Given the assumptions and guidelines discussed above, various preliminary biodiesel use scenarios were analyzed for MDAD airside operations. This involved breaking the current and future inventories into various levels or tiers of acceptable implementation. This facilitated a more thorough analysis of the cost-effectiveness of biodiesel use within the various types of MDAD airside equipment applications and their respective duty cycles. A description and discussion of each tier is presented below, with its respective biodiesel implementation schedule within the MDAD equipment categories shown in Tables 7-2 through 7-7:

7.3.1 Tier 1 Implementation

- This tier describes the initial implementation of biodiesel blends in "non-critical" MDAD airside equipment. Non-critical equipment and vehicles are those not used in police, firefighting or security capacities. In this tier, implementation is restricted to equipment/vehicles built in or after model year 1996 to ensure fuel system materials compatibility with biodiesel. Also included are new vehicles that will be purchased in future years to replace older vehicles being retired according to the previously described retirement schedule of Table 7-1.
- This tier also limits implementation to those vehicles that will consume the fuel they can store onboard in two months or less. Onboard storage durations are based on the maximum time biodiesel fuels can be stored before their quality becomes suspect. It was calculated from individual vehicle tank capacities and average monthly fuel usage rates.
- Equipment/vehicle populations selected in this tier are assumed to be equipped from the factory for biodiesel compatibility, thus it is assumed that biodiesel use begins immediately in calendar year 2004.

7.3.2 Tier 2 Implementation

- Tier 2 involves implementing biodiesel in non-critical airside equipment of model years 1996 and newer. As in Tier 1, it includes future-year replacements according to the retirement schedule.
- Tier 2 limits biodiesel implementation to equipment/vehicles with onboard storage durations of two to four months.
- Biodiesel use for the Tier 2-selected equipment/vehicle populations is assumed to start in calendar year 2006. This delayed implementation was chosen to allow MDAD officials to assess Tier 1 experience with biodiesel for years 2004 and 2005. As part of this experience, it was assumed that regular biodiesel fuel samples would be taken to assess storage stability in the South Florida environment. If the results of these fuel inspections support onboard durations up to four months, biodiesel use in Tier 2 equipment/vehicles can begin in year 2006.

Table 7-2. Numbers of Selected MDAD Equipment by Category for Tier 1 Biodiesel Fuel Implementation

Calendar Year	Generators		Fire Pumps		Pickup (Full-Size)		Truck (MD-HD)		Truck (Maint)		Van		Tractor & Mower		Baggage Tugs	
	Add	Total	Add	Total	Add	Total	Add	Total	Add	Total	Add	Total	Add	Total	Add	Total
2004	0	0	0	0	15	15	7	7	9	9	1	1	10	10	3	3
2005	0	0	0	0	2	17	0	7	0	9	0	1	0	10	2	5
2006	0	0	0	0	0	17	0	7	0	9	0	1	0	10	0	5
2007	0	0	0	0	0	17	0	7	0	9	0	1	0	10	1	6
2008	0	0	0	0	0	17	0	7	0	9	0	1	0	10	0	6
2009	0	0	0	0	0	17	0	7	0	9	0	1	0	10	0	6
2010	0	0	0	0	0	17	0	7	0	9	0	1	0	10	0	6

Table 7-3. Numbers of Selected MDAD Equipment by Category for Tier 2 Biodiesel Fuel Implementation

Calendar year	Generators		Fire Pumps		Pickup (Full-Size)		Truck (MD-HD)		Truck (Maint)		Van		Tractor & Mower		Baggage Tugs	
	Add	Total	Add	Total	Add	Total	Add	Total	Add	Total	Add	Total	Add	Total	Add	Total
2004	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2006	0	0	0	0	1	1	2	2	5	5	0	0	0	0	0	0
2007	0	0	0	0	0	1	0	2	0	5	0	0	0	0	0	0
2008	0	0	0	0	0	1	0	2	0	5	0	0	0	0	0	0
2009	0	0	0	0	0	1	0	2	0	5	0	0	0	0	0	0
2010	0	0	0	0	0	1	0	2	0	5	0	0	0	0	0	0

Table 7-4. Numbers of Selected MDAD Equipment by Category for Tier 3 Biodiesel Fuel Implementation

Calendar Year	Generators		Fire Pumps		Pickup (Full-Size)		Truck (MD-HD)		Truck (Maint)		Van		Tractor & Mower		Baggage Tugs	
	Add	Total	Add	Total	Add	Total	Add	Total	Add	Total	Add	Total	Add	Total	Add	Total
2004	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2006	0	0	0	0	0	0	7	7	1	1	0	0	0	0	0	0
2007	0	0	0	0	0	0	0	7	0	1	0	0	0	0	0	0
2008	0	0	0	0	0	0	0	7	0	1	0	0	0	0	0	0
2009	0	0	0	0	0	0	1	8	0	1	0	0	0	0	0	0
2010	0	0	0	0	0	0	1	9	1	2	0	0	0	0	0	0

Table 7-5. Numbers of Selected MDAD Equipment by Category for Tier 4 Biodiesel Fuel Implementation

Calendar Year	Generators		Fire Pumps		Pickup (Full-Size)		Truck (MD-HD)		Truck (Maint)		Van		Tractor & Mower		Baggage Tugs	
	Add	Total	Add	Total	Add	Total	Add	Total	Add	Total	Add	Total	Add	Total	Add	Total
2004	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2006	0	0	0	0	1	1	6	6	0	0	0	0	0	0	0	0
2007	0	0	0	0	0	1	1	7	0	0	0	0	0	0	0	0
2008	0	0	0	0	0	1	0	7	0	0	0	0	0	0	0	0
2009	0	0	0	0	0	1	0	7	0	0	0	0	0	0	0	0
2010	0	0	0	0	0	1	1	8	0	0	0	0	0	0	0	0

Table 7-6. Numbers of Selected MDAD Equipment by Category for Tier 5 Biodiesel Fuel Implementation

Calendar Year	Generators		Fire Pumps		Pickup (Full-Size)		Truck (MD-HD)		Truck (Maint)		Van		Tractor & Mower		Baggage Tugs	
	Add	Total	Add	Total	Add	Total	Add	Total	Add	Total	Add	Total	Add	Total	Add	Total
2004	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2006	0	0	0	0	2	2	0	0	1	1	0	0	0	0	0	0
2007	0	0	0	0	0	2	0	0	0	1	0	0	0	0	0	0
2008	0	0	0	0	0	2	0	0	0	1	0	0	0	0	0	0
2009	0	0	0	0	0	2	0	0	0	1	0	0	0	0	0	0
2010	0	0	0	0	0	2	0	0	0	1	0	0	0	0	0	0

Table 7-7. Numbers of Selected MDAD Equipment by Category for Tier 6 Biodiesel Fuel Implementation

Calendar Year	Generators		Fire Pumps		Pickup (Full-Size)		Truck (MD-HD)		Truck (Maint)		Van		Tractor & Mower		Baggage Tugs	
	Add	Total	Add	Total	Add	Total	Add	Total	Add	Total	Add	Total	Add	Total	Add	Total
2004	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2006	8	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2007	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2008	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2009	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0

7.3.3 Tier 3 Implementation

- Tier 3 involves implementing biodiesel in non-critical medium and heavy vehicles of model years 1995 and older that have received engine maintenance, overhauls or rebuilds that included fuel system material upgrades for biodiesel.
- Biodiesel implementation in Tier 3 selected equipment/vehicles is limited to those with onboard fuel storage durations of four months or less.
- Tier 3 biodiesel use in refurbished medium and heavy trucks is assumed to start in calendar year 2006. As in Tier 2, delayed implementation will allow MDAD officials to fully assess Tier 1 biodiesel experience in years 2004 and 2005, including fuel stability in relation to the assumed four-month onboard storage limit.

7.3.4 Tier 4 Implementation

- Under this Tier, biodiesel would be introduced into the MDAD "critical" mission equipment/vehicle applications including police, firefighting and security applications. Again, only those critical vehicles of 1996 or later model years are included for biodiesel use. This includes future-year vehicle replacements made according to the retirement schedule.
- Tier 4 also includes critical medium and heavy duty vehicles of model years 1996 and older that have received fuel system refurbishment that included materials upgrades for biodiesel.
- Biodiesel implementation in Tier 4-selected equipment/vehicles is limited to vehicles with onboard storage durations of four months or less.
- Tier 4 biodiesel use was assumed to begin in year 2006 and to be based on MDAD's previous experience and fuel stability test results in 2004 and 2005 (Tier 1).

7.3.5 Tier 5 Implementation

- Tier 5 was assumed to include non-critical equipment/vehicles of model years 1996 and newer. Future scheduled replacements are included.
- Only equipment/vehicles with onboard storage durations of from four to six months were included in Tier 5.
- Biodiesel implementation in Tier 5 starts in year 2006, again contingent on MDAD experience in Tier 1.

7.3.6 Tier 6 Implementation

- Tier 6 implementation would only involve using biodiesel in selected standby generators of 1996 manufacture or newer. None of the fire pumps is included since they are considerably older than 1996 and at greater risk for fuel system materials issues with biodiesel.
- Under this tier, any biodiesel fuel stored in generator service tanks and/or day tanks was assumed to be replaced with fresh fuel after six months.
- Biodiesel use in the selected generators would start in 2006, based on a thorough analysis of Tier 1 fuel storage stability. An assessment will be made in relation to the six-month storage duration allowed in this tier. Some of the generators will not turnover their fuel supply in an acceptable amount of time due to their stand-by use nature.

7.4 BIODIESEL IMPLEMENTATION SCENARIO RESULTS

The results of the tier level implementation of biodiesel within the MDAD airside equipment inventory are shown in Table 7-8. Results are shown as incremental petroleum fuel savings and emission reductions for each of the six tiers over the 2004 through 2010 timeframe. Note that Tier 1 exhibited the largest total VOC emission reductions (about 6.5 tons) and fuel savings (about 60,000 DGE) among the six tiers since it involved the use of biodiesel in the most MDAD equipment. It also starts accruing these benefits immediately in 2004, unlike the other five tiers. The next best tiers from a VOC emission reduction and fuel savings basis were Tiers 3 and 6, respectively. Taken together, the implementation of all six tiers inclusive would result in more than 95,000 DGE fuel savings and almost 7.0 tons of VOC emission reductions over the period of 2004 to 2010. Compared with baseline fuel use and VOC emission levels, the implementation of all six tier together would result in a 12 percent drop in annual fuel use and a 49 percent reduction in annual VOC emissions.

7.5 EQUIPMENT AND REFUELING COSTS FOR BIODIESEL IMPLEMENTATION

Based on the implementation tiers presented above, annual capital and operating costs were estimated for each.

7.5.1 Equipment and Operational Costs

As discussed in Section 5, the incremental costs of operating biodiesel in equipment and vehicles is comprised mainly of those costs for replacing fuel filters in new (1996 and newer model years) equipment and replacing fuel system materials in rebuilt equipment. Fuel filter changeouts are generally less than $50 for parts and labor for most equipment applications. It is recommended that filters are changed within a few weeks of biodiesel use and then under regularly scheduled intervals consistent with conventional diesel use. Fuel system material upgrades for most equipment cost between $300 and $500 for parts and labor.

The other primary cost for biodiesel use relates to the differential cost of the fuel relative to conventional diesel fuel. It was determined that MDAD currently pays about $1.00/gal for conventional diesel fuel on a non-tax basis. Currently, biodiesel (B20) is being sold in South Florida on the same non-tax basis at $1.26/gal.

These capital and fuel costs are reflected in Table 7-9 which lists the incremental equipment capital costs for period of 2004 through 2010. (Costs are shown in 2004 dollars). As shown, Tier 1 has the highest overall incremental equipment costs among the six tiers. It includes two additional years of implementation (years 2004 and 2005) and utilizes biodiesel in a considerably larger number of equipment than any of the other tiers. In total, all tiers implemented together would cost about $133,000 over the period of 2004 through 2010.

TABLE 7-8. TIER IMPLEMENTATION PETROLEUM FUEL SAVINGS AND EMISSIONS REDUCTIONS

Tier	Parameter	Calendar Year							Totals
		2004	2005	2006	2007	2008	2009	2010	
1	**Fuel Savings (DGE)**	8,152	8,583	8,583	8,670	8,670	8,670	8,670	59,998
	VOC (tons)	0.60	0.90	0.89	1.04	1.03	1.05	1.06	6.57
	CO (tons)	17.63	29.18	29.16	34.93	34.93	34.95	34.95	216
	NOx (tons)	0.21	0.33	0.33	0.40	0.40	0.41	0.41	2.50
	PM (tons)	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.37
2	**Fuel Savings (DGE)**	0	0	291	291	291	291	291	1,453
	VOC (tons)	0.00	0.00	0.002	0.002	0.002	0.003	0.003	0.01
	CO (tons)	0.00	0.00	0.006	0.006	0.006	0.006	0.007	0.03
	NOx (tons)	0.00	0.00	-0.001	-0.001	-0.001	-0.001	-0.001	-0.005
	PM (tons)	0.00	0.00	0.001	0.001	0.001	0.001	0.001	0.005
3	**Fuel Savings (DGE)**	0	0	2,432	2,432	2,432	2,598	2,710	12,604
	VOC (tons)	0.00	0.00	0.013	0.013	0.014	0.016	0.019	0.08
	CO (tons)	0.00	0.00	0.044	0.046	0.046	0.056	0.069	0.26
	NOx (tons)	0.00	0.00	-0.036	-0.037	-0.036	-0.043	-0.053	-0.020
	PM (tons)	0.00	0.00	0.005	0.006	0.005	0.007	0.008	0.031
4	**Fuel Savings (DGE)**	0	0	830	1,008	1,008	1,008	1,211	5,066
	VOC (tons)	0.00	0.00	0.007	0.008	0.008	0.009	0.010	0.042
	CO (tons)	0.00	0.00	0.018	0.022	0.022	0.024	0.027	0.120
	NOx (tons)	0.00	0.00	-0.007	-0.009	-0.009	-0.009	-0.011	-0.040
	PM (tons)	0.00	0.00	0.002	0.003	0.003	0.003	0.003	0.014

5	**Fuel Savings (DGE)**	0	0	60	60	60	60	60	299
	VOC (tons)	0.00	0.00	0.002	0.002	0.002	0.002	0.002	0.010
	CO (tons)	0.00	0.00	0.002	0.003	0.003	0.003	0.003	0.014
	NOx (tons)	0.00	0.00	0.003	0.004	0.003	0.004	0.004	0.020
	PM (tons)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	**Fuel Savings (DGE)**	0	0	3,119	3,119	3,119	3,119	3,119	15,596
	VOC (tons)	0.00	0.00	0.016	0.016	0.016	0.016	0.016	0.078
	CO (tons)	0.00	0.00	0.025	0.025	0.025	0.025	0.025	0.127
	NOx (tons)	0.00	0.00	-0.018	-0.018	-0.018	-0.018	-0.018	-0.090
	PM (tons)	0.00	0.00	0.008	0.008	0.008	0.008	0.008	0.038
Totals	**Fuel Savings (DGE)**	8,152	8,583	15,314	15,580	15,580	15,746	16,060	95,015
	VOC (tons)	0.60	0.90	0.93	1.08	1.08	1.10	1.10	6.79
	CO (tons)	17.6	29.2	29.3	35.0	35.0	35.1	35.1	216
	NOx (tons)	0.21	0.33	0.27	0.34	0.34	0.34	0.33	2.18
	PM (tons)	0.05	0.05	0.07	0.07	0.07	0.07	0.07	0.45

TABLE 7-9. INCREMENTAL EQUIPMENT COSTS BY BIODIESEL TIER IMPLEMENTATION

Tier	Incremental Cost Parameter	Incremental Vehicle Capital Costs by Calendar Year ($)							
		2004	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**Totals**
1	Equipment Capital Costs	6825	180	0	450	0	0	0	7,455
	Fuel Costs	8826	9163	9163	9163	9163	9163	9163	63,804
	Totals	**15,651**	**9,343**	**9,163**	**9,613**	**9,163**	**9,163**	**9,163**	**71,259**
2	Equipment Capital Costs	0	0	1483	1483	1483	1483	1483	7,415
	Fuel Costs	0	0	2460	0	0	0	0	2,460
	Totals	**0**	**0**	**3,943**	**1,483**	**1,483**	**1,483**	**1,483**	**9,875**
3	Equipment Capital Costs	0	0	2760	0	0	345	690	3,795
	Fuel Costs	0	0	1885	1885	1885	2129	2546	10,330
	Totals	**0**	**0**	**4,645**	**1,885**	**1,885**	**2,474**	**3,236**	**14,125**
4	Equipment Capital Costs	0	0	2115	345	0	0	345	2,805
	Fuel Costs	0	0	1604	1848	1848	1848	2093	9,241
	Totals	**0**	**0**	**3,719**	**2,193**	**1,848**	**1,848**	**2,438**	**12,046**
5	Equipment Capital Costs	0	0	435	0	0	0	0	435
	Fuel Costs	0	0	443	443	443	443	443	2,215
	Totals	**0**	**0**	**878**	**443**	**443**	**443**	**443**	**2,650**
6	Equipment Capital Costs	0	0	600	0	0	0	0	600
	Fuel Costs	0	0	4546	4546	4546	4546	4546	22,730
	Totals	**0**	**0**	**5,146**	**4,546**	**4,546**	**4,546**	**4,546**	**23,330**

7.5.2 Refueling Infrastructure Costs

Table 7-10 provides a breakdown of biodiesel refueling infrastructure for each tier level of implementation. It was assumed that the infrastructure installed for a given tier level would satisfy the needs of the equipment it was serving while at the same time limiting the storage duration of the fuel to two months or less. This was done to ensure the biodiesel fuel is turned over frequently to reduce fuel stability and biogrowth issues.

As noted in Section 6, two locations are currently used by MDAD equipment for refueling: Location O and the 20th Street fuel facility. It was assumed that biodiesel refueling infrastructure would be placed at these two locations as well. Location O serves the baggage tugs and the tractor/mowers. Since the existing diesel tanks there refuel tenant equipment, a dedicated biodiesel tank would be needed. Thus, a new 500 gallon underground tank was assumed to be installed at Location O for tier levels involving the implementation of biodiesel in baggage tugs and tractors/mowers. Alternatively, the 20th Street facility fuels the remaining MDAD equipment so a substantially larger amount of biodiesel would be needed at this location. Similar to Location O, the 20th Street fuel facility also refuels tenant operations. Based on discussions with MDAD personnel, it is known that three, 2,000 gallon aboveground tanks are currently not in use. It was assumed that these tanks could be put into service as needed for biodiesel. For most of the tier levels, two of the 2,000 gallon aboveground tanks were assumed to be placed at the 20th Street location for biodiesel service. Costs for these tanks involved cleaning and installation. In other cases, a small new tank was installed as appropriate. Finally, in the case of tier 6 which involved the use of biodiesel in generators only, it was assumed that the tanks currently serving the generators would be cleaned out and reused for biodiesel.

Note that the refueling infrastructure costs for Tier 1 are the highest because of the need to place a new tank at Location O and two of the 2,000 gallon tanks at the 20th Street fuel facility.

7.6 COST-BENEFIT ANALYSIS

Capital costs of equipment and infrastructure and fuel costs for each scenario were annualized in order to perform a cost benefit analysis on each tier. Two cost-benefit measurements were employed for purposes of this study: $/GGE$_{reduced}$ and $/ton $_{VOC\ reduced}$. Both of these measures relate directly to MDAD's 2010 goals for fuel and VOC emission reductions relative to the 2003 baseline. They also allow comparisons with various alternative fuel technology scenarios developed under the AFMP and being considered by MDAD management. The annualized costs of each scenario were divided by the annualized fuel savings and VOC emissions, respectively, to determine the cost-benefit ratios.

Table 7-11 lists the results of the cost-benefit analysis for each tier level of implementation. Overall, Tier 1 had the best cost-effectiveness for the combination of VOC emissions reduction and fuels savings. Tier 1 had the best for VOC emission reductions, while Tier 3 exhibited the best cost effectiveness for fuel savings. The worst combined cost-effectiveness was found with Tier 2. None of the tier levels were found to have particularly cost-effective VOC emission reduction.

TABLE 7-10. INCREMENTAL REFUELING STATION CAPITAL COSTS BY SCENARIO

Scenario	Location	Description	Tank Size (Gal)	Incremental Refueling Station Capital Costs by Calendar Year ($)							Totals
				2004	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	
1	Location O	AST	500	12,000	0	0	0	0	0	0	12,000
	20th St.	AST(2)	2,000 each	3,000	0	0	0	0	0	0	3,000
			Totals	**15,000**	**0**	**0**	**0**	**0**	**0**	**0**	**15,000**
2	Location O	None	---	0	0	0	0	0	0	0	0
	20th St.	AST	500	12,000	0	0	0	0	0	0	12,000
			Totals	**12,000**	**0**	**0**	**0**	**0**	**0**	**0**	**12,000**
3	Location O	None	---	0	0	0	0	0	0	0	0
	20th St.	AST(2)	2,000 each	3,000	0	0	0	0	0	0	3,000
			Totals	**3,000**	**0**	**0**	**0**	**0**	**0**	**0**	**3,000**
4	Location O	None	---	0	0	0	0	0	0	0	0
	20th St.	AST	500	12,000	0	0	0	0	0	0	12,000
			Totals	**12,000**	**0**	**0**	**0**	**0**	**0**	**0**	**12,000**
5	Location O	None	---	0	0	0	0	0	0	0	0
	20th St.	AST	500	12,000	0	0	0	0	0	0	12,000
			Totals	**12,000**	**0**	**0**	**0**	**0**	**0**	**0**	**12,000**
6	Location O	None	---	0	0	0	0	0	0	0	0
	Gen. tanks	None	---	8,000	0	0	0	0	0	0	8,000
			Totals	**8,000**	**0**	**0**	**0**	**0**	**0**	**0**	**8,000**

TABLE 7-11. SUMMARY OF IMPLEMENTATION TIER COST-EFFECTIVENESS

Tier	Year	Total Fuel Savings (DGE)	Total VOC Reductions (Tons)	Total Incr Cost ($)	Cost-Effectiveness Measures	
					$/DGE	$/ton
1	2004	8,152	0.60	10,259	1.26	17,098
	2005	8,582	0.90	9,931	1.16	11,035
	2006	8,582	0.90	9,913	1.16	11,015
	2007	8,670	1.04	9,951	1.15	9,568
	2008	8,670	1.03	9,946	1.15	9,657
	2009	8,670	1.05	9,946	1.15	9,473
	2010	8,670	1.06	9,946	1.15	9,383
				Average Cost-Effectiveness	**1.16**	**10,622**
2	2004	0	0	0	0	0
	2005	0	0	0	0	0
	2006	291	0.002	2,279	7.83	1,139,66
	2007	291	0.002	2,033	6.99	1,016,666
	2008	291	0.002	2,033	6.99	1,016,666
	2009	291	0.002	2,033	6.99	677,777
	2010	291	0.003	2,033	6.99	677,777
				Average Cost-Effectiveness	**7.16**	**867,721**
3	2004	0	0	0	0	0
	2005	0	0	0	0	0
	2006	2,432	0.013	2,311	0.95	177,745
	2007	2,432	0.013	2,035	0.84	156,514
	2008	2,432	0.013	2,035	0.84	145,334
	2009	2,598	0.013	2,314	0.89	144,619
	2010	2,710	0.013	2,765	1.02	145,515
				Average Cost-Effectiveness	**0.93**	**156,117**
4	2004	0	0	0	0	0
	2005	0	0	0	0	0
	2006	830	0.007	2,365	2.85	337,896
	2007	1,008	0.008	2,433	2.41	304,124
	2008	1,008	0.008	2,398	2.38	299,811
	2009	1,008	0.009	2,398	2.38	266,499
	2010	1,211	0.010	2,678	2.21	267,770
				Average Cost-Effectiveness	**2.42**	**292,213**
5	2004	0	0	0	0	0
	2005	0	0	0	0	0
	2006	60	0.002	1,036	17.27	148,023
	2007	60	0.002	993	16.54	124,083
	2008	60	0.002	993	16.54	124,083
	2009	60	0.002	993	16.54	110,296
	2010	60	0.002	993	16.69	99,266
				Average Cost-Effectiveness	**16.69**	**119,210**
6	2004	0	0	0	0	0
	2005	0	0	0	0	0
	2006	3,119	0.016	5,006	1.61	312,893
	2007	3,119	0.016	4,946	1.59	309,143
	2008	3,119	0.016	4,946	1.59	309,143
	2009	3,119	0.016	4,946	1.59	309,143
	2010	3,119	0.016	4,946	1.59	309,143
				Average Cost-Effectiveness	**1.59**	**309,893**

7.7 OVERALL BIODIESEL IMPLEMENTATION RECOMMENDATIONS

Overall, this study has shown that biodiesel is a cost-effective means of achieving lower fuel consumption and reduced emissions for the MDAD airside equipment inventory. A straightforward implementation approach for biodiesel use was presented which would allow MDAD management to assess initial experience with the fuel before widening its application within the inventory. However, a closer review of the tier level results of the implementation is warranted and will allow an even more streamlined and cost-effective approach.

7.7.1 Final Recommended Implementation

Based on the six tier levels of implementation presented for biodiesel introduction into the MDAD airside equipment inventory, it is recommended that Tiers 1 and 3 be given greater initial consideration than the rest. As shown in Table 7-12, both tiers provide significant VOC emission reductions and fuel savings over the period of year 2004 to 2010, and combined result in cost-effective means of achieving MDAD's 2010 goals for VOC and petroleum fuel reductions at the airport. Tier 1 would start as planned in year 2004 and proceed through year 2010. This includes the newer vehicles in the inventory with higher fuel use. Over the course of years 2004 and 2005, it is recommended that MDAD take fuel samples on a monthly basis to ascertain how stable the regional biodiesel supply is and how well the fuel holds up to long-term storage. Assuming the fuel quality results and overall fleet experience is favorable under Tier 1 in years 2004 and 2005, MDAD would then institute Tier 3 in year 2006 through 2010. As prescribed under Tier 3, this would involve the introduction of heavy trucks that have been upgraded for biodiesel use as part of normal engine rebuild cycles. Based on biodiesel fuel consumption levels estimated for Tiers 1 and 3 inclusive, the necessary biodiesel refueling infrastructure would consist only of one new 500 gallon aboveground tank and dispenser in Location O, and two refurbished 2,000 gallon tanks and dispenser installed at the 20th Street fuel facility location.

TABLE 7-12. RESULTS OF RECOMMENDED IMPLEMENTATION: TIER 1 AND 3

Year	Fuel Savings (DGE)	VOC Reductions (ton)	Annual Incr Cost ($)	$/DGE	$/ton VOC
2004	8,152	0.60	9,509	1.17	15,848
2005	8,582	0.90	9,181	1.07	10,201
2006	11,014	0.91	12,074	1.10	13,225
2007	11,102	1.05	11,836	1.07	11,240
2008	11,102	1.17	11,831	1.07	10,112
2009	11,268	1.07	12,110	1.07	11,360
2010	11,380	1.08	12,561	1.10	11,641
Totals	**72,600**	**6.78**	**79,102**	**1.09Avg**	**11,665 Avg**

It should be noted that while the combined Tier 1 and 3 implementation presented here provides a reasonable introduction for biodiesel in MDAD's airside inventory, the equipment turnover schedule assumed for this study strongly influenced these final results. A different equipment turnover schedule than that assumed for this study could result in a slightly different implementation through 2010. For this reason, it is recommended that some additional review and analysis of MDAD airside fleet needs over the period of 2004 through 2010 be conducted to "fine tune" the final recommended biodiesel implementation.

7.7.2 Additional Considerations

7.7.2.1 Further Biodiesel Implementation

While the results of some of the other implementation tiers (Tiers 4 and 6) discussed above in section 7.6 were marginally promising in terms of their VOC emission and fuel reductions and their overall cost-effectiveness, critical review should be conducted before their inclusion in the implementation schedule. Tier 4 relates to the use of biodiesel in "critical" mission vehicles such as police, security, and fire and rescue. While biodiesel use in these vehicles should not impact their operation or performance, additional considerations are involved in including these vehicles. Additionally, Tier 4 allows a more aggressive onboard storage duration (up to four months) which must be assessed in relation to Tier 1 experience and fuel testing.

Tier 6 involves the use of biodiesel in some of the newer standby generators in the MDAD inventory. Since they are late model generators, issues with material compatibility should not be an issue. The bigger question concerning their inclusion in the biodiesel implementation schedule is their standby duty cycles. Many of these generators can experience months of inactivity. (The fuel use figures presented for Tier 6 were based on annual average hours of operation for the generators. Actual operation can vary significantly from month to month.)

The older generators as well as all of the fire pumps should remain unavailable for biodiesel due to their age. The majority of this equipment are driven by diesel engines embodying technology well over a decade old. For example, there are 10 gen sets driven by Caterpillar engines that are no longer produced (300-Series model designations). Caterpillar continues to support these machines with parts and service, but even with fuel system upgrades it's unlikely they can perform as well, from either the emissions or fuel consumption standpoints, as newer, direct-injection engines with electronic controls. Replacement of a functional unit generally isn't warranted before it has come to the end of its useful life. However, replacement of the oldest units with current-technology diesel gen sets will probably afford worthwhile improvements of both emissions and fuel consumption and allow greater use of biodiesel.

7.7.2.2 Future Fleet Management Needs

EA recommends that MDAD adopt additional fleet management tools to centralize and expand the management of fleet data in general, and to track biodiesel fuel use, maintenance and operation, in particular. Biodiesel storage, especially, should be monitored both in bulk storage tanks and within vehicles to eliminate issues with stability and microbial growth. Detailed fuel sampling data should be collected regularly to track fuel quality and anticipate problems. Data on biodiesel use in equipment should also be tracked closely to assess difference in operation as they occur so as to apply to lessons learned in the future.

7.7.2.3 Impacts of New Conventional Diesel Equipment

It should be noted that the simple replacement of older conventional diesel equipment not being targeted for biodiesel use with new technology diesel vehicles could also afford significant fuel savings and VOC emission reduction benefits in their own right for the MDAD airside fleet when compared with the baseline. Therefore, in concert with the implementation of biodiesel in specific applications, a parallel plan for retiring older conventional diesel equipment and replacing them with new conventional diesel equipment should be established. The continuance of such a retirement plan should then be made part of normal fleet management practices.

7.7.2.4 Future Changes to Fuels

Within the time frame considered in this study, diesel fuels will undergo significant changes, due mainly to new Federal regulations on fuel quality. Beginning in mid-2006, highway diesel fuel will be limited to a sulfur content of 15 parts per million (ppm), compared to the current limit of 500 ppm (the current national average sulfur content is about 350 ppm). There are some exceptions in the regulation for small refiners and special cases, but the EPA estimates that well over 90 percent of the nation’s fuel will comply with the new sulfur limit when it goes into effect.

The U.S. Environmental Protection Agency will require non-road diesel fuel meet a 500 ppm sulfur specification by 2007 or 2008. This is a very substantial reduction from the current limit of 5,000 ppm. The EPA is believed ultimately to want all diesel fuels, on-road and non-road, to meet the 15 ppm average sulfur content of ultra-low sulfur diesel (ULSD) mentioned above.

When diesel fuel sulfur is drastically reduced, fuel lubricity generally suffers. This could provide an additional opportunity (and motivation) to blend biodiesel with petroleum diesel fuels, since at even the two-to-three percent level, biodiesel can double the lubricity of diesel fuel. Deeper desulfurization will also raise the price of diesel fuels, at least temporarily. Blending these higher-quality, higher-price fuels with biodiesel may make more sense than blending biodiesel into today’s higher-sulfur fuels. The incremental price of the biodiesel portion will be a smaller percentage of the lower-sulfur fuels’ cost than of today’s fuel prices, and the lubricity enhancement may be of significantly greater value.

7.7.2.5 Public Outreach

As part of this study, a focused outreach program aimed at airport tenant and regional airport organizations is planned. Outreach/educational materials will be developed describing the benefits, costs, and applications for biodiesel airside applications that can be used for direct mailing to prospective fleet users. A workshop should also be held for MIA tenants, as well as other regional airport representatives as a means of educating potential end users on MIA’s plans for biodiesel and to broaden and secure the regional support coalition. It is also anticipated that County representatives will present the results of this study at Regional Planning Council meetings and Gold Coast Clean Cities program meetings. Finally, it is recommended that the results of this study be posted in MDAD's website as a means of reaching a broader regional audience.

Appendix A: MDAD Airside Equipment Inventory and Operational Data

Table A-1: Current MDAD Diesel Pickup Truck Inventory

Vehicle Type	Veh.#	Make	Model	Year	Total Mileage	Annual Mileage	Vehicle Age (yr.)	City Fuel Econ (mpg)	Price	Classification
Pickup-Fullsize	**19459**	Chevrolet	3/4 ton pickup	1995	97728	12216	8	14	$ 17,395	Electrical Shop
Pickup-Fullsize	**13-1760**	Ford	F350	1995	85839	10730	8	13	$ 26,131	Grounds
Pickup-Fullsize	**13-1841**	Ford	F350	1996	87623	12518	7	13	$ 26,132	Grounds
Pickup-Fullsize	**13-1759**	Ford	F350	1995	74408	9301	8	13	$ 26,131	Grounds
Pickup-Fullsize	**13-1882**	Ford	F350	1995	61058	7632	8	13	$ 26,132	Grounds
Pickup-Fullsize	**13-1989**	Ford	F450	1995	4650	581	8	13	$ 54,336	Police
Pickup-Fullsize	**13-1840**	Ford	F350	1996	52134	7448	7	13	$ 26,132	Grounds
Pickup-Fullsize	**13-1842**	Ford	F350	1996	70038	10005	7	13	$ 26,132	Grounds
Pickup-Fullsize	**13-1843**	Ford	F350	1996	72181	10312	7	13	$ 26,132	Grounds
Pickup-Fullsize	**20951**	Ford	F250 4X2	1997	52676	8779	6	14	$ 30,607	Public Works
Pickup-Fullsize	**13-2025**	Chevrolet	C2500 1 ton 4x2	1997	52787	8798	6	15	$ 24,908	Landscape
Pickup-Fullsize	**13-2052**	Ford	F550	1998	60210	12042	5	12	$ 43,984	Fire
Pickup-Fullsize	**13-2058**	Ford	F350	2000	34147	11382	3	14	$ 30,095	Landscape
Pickup-Fullsize	**24209**	Dodge	1 ton pickup	2000	1240	413	3	13	$ 24,999	Garage
Pickup-Fullsize	**13-2056**	Ford	F350	2000	3491	1164	3	14	$ 31,998	Garage
Pickup-Fullsize	**13-2128**	Dodge	Ram 3500	2001	23370	11685	2	13	$ 31,354	Airfield lighting
Pickup-Fullsize	**13-2129**	Dodge	Ram 3500	2001	21832	10916	2	13	$ 31,354	Airfield lighting
Pickup-Fullsize	**13-2130**	Dodge	Ram 3500	2001	18825	9413	2	13	$ 31,354	Airfield lighting
Pickup-Fullsize	**21-0318**	Ford		2001	8209	4105	2	13	$ 156,390	Fire
Pickup-Fullsize	**5-0483**	Ford	3500	2001	3224	1612	2	13	$ 28,105	Mechanical Maintenance
Pickup-Fullsize	**13-2254**	Dodge	Ram pickup	2002	425	425	1	13	$ 26,247	Garage
Pickup-Fullsize	**13-2261**	Ford	F350 crew cab	2002	56	56	1	14	$ 25,234	Grounds
Pickup-Fullsize	**13-2262**	Ford	F350 crew cab	2002	5806	5806	1	14	$ 25,234	Grounds
Pickup-Fullsize	**13-2263**	Ford	4x2 pickup	2002	5312	5312	1	14	$ 25,234	Grounds
Pickup-Fullsize	**13-2264**	Ford		2002	1356	1356	1	14	$ 25,234	Grounds
Pickup-Fullsize	**13-2265**	Ford		2002	7374	7374	1	14	$ 25,234	Grounds
Pickup-Fullsize	**13-2266**	Ford		2002	36	36	1	14	$ 25,033	Electrical Shop
Pickup-Fullsize	**13-2268**	Ford		2002	1394	1394	1	14		Police
Pickup-Fullsize	**13-2353**	Ford		2003	60	60	0	14	$ 24,696	Grounds

Table A-2: Current MDAD Diesel Medium- and Heavy-Duty Truck Inventory

Vehicle Type	Veh.#	Make	Model	Year	Total Mileage	Annual Mileage	Vehicle Age (yr.)	City Fuel Econ (mpg)	Price	Classification
Truck-Dump	**4-0244**	Ford	16-ft dump truck	1989	77200	5514	14	6.5	$ 52,353	Public Works
Truck-Dump	**4-0237**	Ford	15-ft dump truck	1991	213022	17752	12	6.5	$ 52,353	Public Works
Truck-Dump	**4-0258**	Ford	16-ft dump truck	1994	69440	7716	9	6.5	$ 53,311	Public Works
Truck-Dump	**4-0259**	Ford	16-ft dump truck	1994	31113	3457	9	6.5	$ 53,311	Public Works
Truck-Dump	**4-0260**	Ford	16-ft dump truck	1994	42611	4735	9	6.5	$ 53,311	Public Works
Truck-Fire	**21-0136**	Oshkosh	Fire truck	1983	16269	813	20	6.5		
Truck-Fire	**21-0170**	E-One	Fire truck	1987	94511	5907	16	6.5		
Truck-Fire	**21-0172**	Oshkosh	Fire truck	1990	87189	6707	13	6.5		
Truck-Fire	**21-0195**	Oshkosh	Fire truck	1993	59400	5940	10	6.5		
Truck-Fire	**21-0204**	Oshkosh	Fire truck	1994	19410	2157	9	6.5		
Truck-Fire	**21-0206**	Oshkosh	Fire truck	1995	28080	3510	8	6.5		
Truck-Fire	**21-0227**	Frt. Liner	Fire truck	1996	76179	10883	7	6.5		
Truck-Fire	**21-0231**	Saulsbury	Fire truck	1997	443	74	6	6.5	$ 135,230	
Truck-Fire	**21-0319**	E-One	Fire truck	2001	2673	1337	2	6.5	$ 535,000	
Truck-Fire	**21-0320**	E-One	Fire truck	2002	1075	1075	1	6.5	$ 696,436	
Truck-Fire	**21-0356**	Freightliner	Fire truck	2003	642	642	1	6.5	$ 154,694	
Truck-HD	**11-0267**	Ford	Semi	1991	113199	9433	12	6.5	$ 57,511	Mobile Garage
Truck-HD	**11-0306**	Peterbilt	Semi	1995	71489	8936	8	6.5		Public Works
Truck-HD	**11-0307**	Peterbilt	Semi	1995	49550	6194	8	6.5		Public Works
Truck-HD	**11-0391**	Mack	Tandem tractor	1998	17424	3485	5	6.5	$ 100,000	Waste Facility
Truck-HD	**11-0392**	Mack	Tandem tractor	1998	24810	4962	5	6.5	$ 100,000	Waste Facility
Truck-HD	**5-0490**	Sterling		2002	3943	3943	1	6.5	$ 177,400	Mechanical Maintenance
Truck-MD	**5-0281**	Ford	CF7000	1990	15811	1216	13	6.5	$ 27,210	Garage
Truck-MD	**26-0224**	Ford	Tow	1992	95756	8705	11	6.5	$ 26,640	Garage
Truck-MD	**10-0081**	Ford	F800	1995	45000	5625	8	6.5	$ 36,659	Landscape
Truck-MD	**26-0246**	Chevrolet	1 ton tow	1995	95006	11876	8	6.5	$ 37,246	Landside Ops
Truck-MD	**5-0370**	Ford	F800	1996	8366	1195	7	6.5	$ 35,982	Public Works
Truck-MD	**5-0371**	Ford	F800	1996	11872	1696	7	6.5	$ 30,697	Landscape
Truck-MD	**9-0087**	Ford	F800 bucket truck	1997	17605	2934	6	6.5	$ 85,494	Grounds
Truck-MD	**26-0268**	Ford	F450	2000	47845	15948	3	6.5	$ 54,000	Landside Ops
Truck-MD	**26-0269**	Ford	F450	2000	59803	19934	3	6.5	$ 55,907	Landside Ops
Truck-MD	**5-0478**	Ford	Sterling	2001	1030	515	2	6.5	$ 55,907	Facilities
Truck-MD	**5-0497**	Ford	Truck	2002	4436	4436	1	6.5	$ 40,215	Paint Shop
Truck-MD	**9-0132**	Ford		2002	36	36	1	6.5	$ 25,704	Plumbing

Table A-3: Current MDAD Diesel Miscellaneous Maintenance Truck Inventory

Vehicle Type	Veh.#	Make	Model	Year	Total Mileage	Annual Mileage	Vehicle Age (yr.)	City Fuel Econ (mpg)	Price	Classification
Truck-Misc Maint.	**20-0150**	Case	Loader	1977	11264	433	26	6.5		Public Works
Truck-Misc Maint.	**4822**	Bobcat		1990	6301	485	13	6.5		Public Works
Truck-Misc Maint.	**9-0074**	Ford		1990	32162	2474	13	6.5	$ 40,279	Building 3038
Truck-Misc Maint.	**7-0364**	Ford	Trash dump truck	1991	167120	13927	12	6.5	$ 41,412	Public Works
Truck-Misc Maint.	**9131**	Caterpillar	Bulldozer	1993	1026	103	10	6.5	$ 88,509	Public Works
Truck-Misc Maint.	**9388**	Champion	Grader	1993	892	89	10	6.5		Public Works
Truck-Misc Maint.	**9763**	Case	Roller	1993	650	65	10	6.5		Public Works
Truck-Misc Maint.	**17-0043**	GMC	Elgin Sweeper	1999	128458	32115	4	6.5	$ 123,082	Public Works
Truck-Misc Maint.	**20-0251**	Bobcat	Loader	1996	12316	12316	7	6.5		Projects
Truck-Misc Maint.	**40997**	American-Lincoln	Scrubber	1996	5694	813	7	6.5		Warehouse
Truck-Misc Maint.	**23-4773**	Vermeer	Chipper	1996	94	13	7	6.5		Grounds
Truck-Misc Maint.	**5-0369**	Ford	Thermolay UD625	1997	37879	6313	6	6.5	$ 100,638	Public Works
Truck-Misc Maint.	**17-0044**	GMC	Elgin Sweeper	1998	42875	8575	5	6.5	$ 123,082	Public Works
Truck-Misc Maint.	**20-0309**	Caterpillar	Backhoe	1998	28881	5776	5	6.5	$ 99,041	Public Works
Truck-Misc Maint.	**20-0310**	Caterpillar	Loader	1998	5566	1113	5	6.5	$ 104,932	Public Works
Truck-Misc Maint.	**23-4864**	American-Lincoln	Scrubber	1999	1302	326	4	6.5	$ 53,754	Public Works
Truck-Misc Maint.	**9-0119**	Sterling	Bucket truck	1999	8066	2017	4	6.5	$ 19,100	Electrical Shop
Truck-Misc Maint.	**23-4865**	American-Lincoln	Scrubber	2000	4666	1555	3	6.5	$ 53,754	Public Works
Truck-Misc Maint.	**17-0052**	Sterling	Sweeper	2001	12035	6018	2	6.5	$ 131,580	Public Works
Truck-Misc Maint.	**17-0053**	Sterling	Sweeper	2001	13746	6873	2	6.5	$ 128,739	Public Works
Truck-Misc Maint.	**17-0061**	Sterling	Vactor sewer	2001	5831	2916	2	6.5	$ 187,971	Public Works
Truck-Misc Maint.	**23-4877**	American-Lincoln	Scrubber	2001	2345	1173	2	6.5	$ 61,972	Public Works
Truck-Misc Maint.	**23-4878**	American-Lincoln	Scrubber	2001	2166	1083	2	6.5	$ 61,972	Public Works
Truck-Misc Maint.	**26269**	Ditch Witch		2002	8055	8055	1	6.5		Public Works
Truck-Misc Maint.	**17-0056**	Tennant	Vacuum	2002	269	269	1	6.5	$ 25,000	Grounds
Truck-Misc Maint.	**17-0057**	Tennant	Vacuum	2002	519	519	1	6.5	$ 25,000	Grounds
Truck-Misc Maint.	**17-0058**	Tennant	Vacuum	2002	652	652	1	6.5	$ 25,000	Grounds
Truck-Misc Maint.	**17-0059**	Tennant	Vacuum	2002	94	94	1	6.5	$ 25,000	Grounds
Truck-Misc Maint.	**17-0060**	Tennant	Vacuum	2002	1	1	1	6.5	$ 25,000	Grounds
Truck-Misc Maint.	**7-0514**	Sterling	Vactor sewer	2003	1014	1014	0	6.5	$ 47,995	Public Works

Table A-4: Current MDAD Diesel Van Inventory

Vehicle Type	Veh.#	Make	Model	Year	Total Mileage	Annual Mileage	Vehicle Age (yr.)	City Fuel Econ (mpg)	Price	Classification
Van-Large	**13-2070**	GMC	Walk-in step van	1999	22366	5592	4	10	$ 36,243	Filter Crew

Table A-5: Current MDAD Diesel Tractor and Mower Inventory

Vehicle Type	Veh.#	Make	Model	Year	Total Mileage	Annual Mileage	Vehicle Age (yr.)	Price	Classification
Mower	**6375B**	Ford	Mower	1990	33296	2561	13		Public Works
Mower	**6374B**	Ford	Mower	1994	22874	2542	9		Grounds
Mower	**6392B**	Ford	Mower	1994	235	26	9		Grounds
Mower	**41011**	John Deere	Tractor	1996	810	116	7		Grounds
Mower	**16-0538**	John Deere	Mower/tractor	2001	324	162	2	$ 16,606	Grounds
Mower	**16-0539**	John Deere	Mower/tractor	2001	1480	740	2	$ 32,015	Grounds
Mower	**16-0541**	John Deere	Mower/tractor	2001	1268	634	2	$ 32,015	Grounds
Mower	**25-3148**	Toro	Mower	2002	55	55	1	$ 12,377	Grounds
Truck-Misc Maint.	**49006-GT**	John Deere		2002	206	206	1		Spray Crew
Truck-Misc Maint.	**49007-GT**	John Deere		2002	183	183	1		Spray Crew

Table A-6: Current MDAD Baggage Tug (Gasoline) Inventory

Vehicle Type	Veh.#	Make	Model	Year	Total Mileage	Annual Mileage	Vehicle Age (yr.)	Price	Classification
Baggage Tug	**7-0217**	Tug		1990	37167	2859	13		Terminal Ops
Baggage Tug	**7-0598**	Tug		1990	17138	1318	13		Terminal Ops
Baggage Tug	**7-0599**	Tug		1990	25374	1952	13		Terminal Ops
Baggage Tug	**9-0414**	Tug		1993	24918	2492	10		Terminal Ops
Baggage Tug	**9-0415**	Tug		1993	9932	993	10		Terminal Ops
Baggage Tug	**9-0416**	Tug		1993	9416	942	10		Terminal Ops
Baggage Tug	**9-0418**	Tug		1993	6554	655	10		Terminal Ops
Baggage Tug	**4-0910**	Tug	Tug	1995	5598	700	8		Terminal Ops
Baggage Tug	**4-0911**	Tug	Tug	1995	4659	582	8		Terminal Ops
Baggage Tug	**4-0936**	Tug	Tug	1995	35313	4414	8	$ 16,850	Terminal Ops
Baggage Tug	**4-6625**	Tug	Tug	1997	6026	1004	6	$ 16,700	Terminal Ops
Baggage Tug	**4-6627**	Tug	Tug	1997	5251	875	6	$ 16,700	Terminal Ops
Baggage Tug	**7-7852**	Tugs	5 tugs	2002		7828	1	$168,860	Terminal Ops

Table A-7: Current MDAD Stationary Generator Inventory

Control No.	Gen Set Location	Gen Set Mfgr.	Model	Serial No.	HP	kW	kVA	Total Hrs.10/'01-03/03, incl.	Avg. Monthly Hrs.
101	MIA Central Gate	Katolight	D25FDP4	n/a	42	25	25	129.8	7.2
102	MIA North Gate	DMT Corp	DMT 20C	n/a	34	20	20	unknown	unknown
103	MIA Northeast Gate	DMT Corp	DMT 20C	91201-4	34	20	20	129.5	7.2
104	MIA Southeast Gate	DMT Corp	DMT 20C	91201-1	34	20	20	0	0
105	MIA Tunnel Gate	DMT Corp	DMT 20C	91201-2	34	20	20	0	0
106	MIA Bldg. 3025	*Rogers Diesel*	PE-85G	92	35	25	31.2	unknown	unknown
107	Homestead Gen'l AFL			n/a	42	35	43	138	7.7
108	MIA Bldg. 2122	Kohler	50R0Z271	178182	72	50	83	0	0
109	MIA E Remote	Onan		6196351	72	50	82.5	8.9	0.5
110	MIA Southwest Gate	Kohler	30R0Z161	371224	80	33	33	0	0
111	MIA Northwest Gate	Kohler	40R0Z161	270485	80	37	50	0	0
112	KTA AFL Vault	Onan		n/a	90	80	100	22	1.2
113	MIA LS No. 12	Caterpillar	3304	4B-8071	166	106	150	unknown	unknown
114	MIA LS No. 68	Katolight	D125FRJ4	AD20689SRD	200	125	150	5.8	0.3
115	MIA LS No. 69	Katolight	D135FRJ4	AD211180S1C	200	135	168	10	0.6
116	MIA H-1461 (H-1)	Caterpillar	342C	49B102	245	150	167	0	0
117	T&T AFL Vault	Caterpillar	343	n/a	390	250	312	338	18.8
118	MIA CCPE E. Plant	Onan	n/a	30318280	390	250	312	0	0
119	OPA AFL Vault	Caterpillar	340	n/a	405	275	344	0	0
120	MIA TEN (small)	Caterpillar	D343	62B10193	415	356		0	0
121	MIA Park #1 - #2	Onan	n/a	10439	432	300	375	0	0
122	MIA Bldg. 33	Katolight	33SR9E	63350	432	300	375	6.6	0.4
123	MIA E-1345	Caterpillar	397	41B1191	450	300	375	0	0
124	MIA Bldg. 60	Caterpillar	379	68B422	500	350	438	0	0
125	Homestead Gen'l Bldg.	n/a	n/a	n/a	n/a	n/a	n/a	unknown	unknown
201	MIA Bldg. 3090	GM EMD	16-645-F33		432	300	375	6	0.3
202	MIA AFL Vault 2	Caterpillar	3412		450	300	375	0	0
203	MIA E-1786 (E-4)	Caterpillar	3412		500	350	438	0	0
204	MIA Bldg. 3202	Caterpillar	D348				2500	0	0
205	MIA S-1605 E. Satellite	Caterpillar	D348		749	500	625	33	1.8
206	MIA Park 2	Caterpillar	3508		750	520	650	0	0
207	MIA Park 4	Caterpillar	348		805	600	750	11	0.6

Table A-7: Current MDAD Stationary Generator Inventory (contd.)

Control No.	Gen Set Location	Gen Set Mfgr.	Model	Serial No.	HP	kW	kVA	Total Hrs.10/'01-03/03, incl.	Avg. Monthly Hrs.
208	MIA Bldg. 100	Cummins			805	565	706	9.5	0.5
209	MIA F-1620 #2 FG Wrap	Katolight	KTA38-G51		825	750	937	5	0.3
210	MIA F-1620 #1 FG Wrap	Katolight	KTA38-G51		890	620	775	5	0.3
211	MIA E-2599 FIS Bldg.	Caterpillar	D399		900	600	625	67.8	3.8
212	KTA AFL Vault 1	Cummins			1340	900	1125	0	0
213	MIA H-1827	Onan	10DFJD		1490	750	938	0	0
214	MIA F-1813 F9/F11	Caterpillar	3512		1588	1100	1375	15.3	0.8
215	MIA D-1 Connector	Caterpillar	D3512		1617	1500	1875	33	1.8
216	MIA TEN (large)	Caterpillar	3512		2027	1400	1750	6.7	0.4
217	MIA A-1139	Caterpillar	3516		2123	2000	1375	7.9	0.4
218	MIA Bldg. 5	Alco			2681	1800	2250	19	1.1
219	MIA CC-A Throat	n/a	n/a	n/a	n/a	n/a	n/a	79	4.4
220	MIA Park 7	na	n/a	n/a	n/a	n/a	n/a	0	0
221	MIA AFL Vault 3	na	n/a	n/a	n/a	n/a	n/a	18.3	1
222	OPA New AFL Vault	n/a	n/a	n/a	n/a	n/a	n/a	0	0
223	MIA NW Retention Pond	n/a	n/a	n/a	n/a	n/a	n/a	3	0.2

Appendix B: Materials Compatibility References

1. Reed, T.B., "An Overview of the Current Status of Biodiesel," First Biomass Conference of the Americas, Vol. 2, pp. 797-814.

2. Holmberg, W.C., "National Soydiesel Development Board Standards for Biodiesel," First Biomass Conference of the Americas, Vol. 2, pp. 876-890.

3. Spataru, A. and C. Romig, "Emissions and Engine Performance from Blends of Soya and Canola Methyl Esters with ARB #2 Diesel in a DDC 6V92TA MUI Engine," SAE Paper 952388, 1995.

4. Schumacher, L., et al., "100,000 Miles of Fueling 5.9l Cummins Engines with 100% Biodiesel," SAE Paper 962233, 1996.

5. Bessee, G. and Joseph Fey, "Compatibility of Elastomers and Metals in Biodiesel Fuel Blends," SAE Paper 971690, 1997.

6. Harrigan, H., et al., "A Rational Approach to Qualifying Materials for Use in Fuel Systems," SAE Paper 2000-01-2013, 2000.

7. Chase, C., and C. Peterson, "A 322,000-Kilometer (200,000 Mile) Over-the-Road Test With Hysee Biodiesel in a Heavy-Duty Truck," SAE Paper 2000-01-2647, 2000.

8. Maxson, M.T., et al., "Performance in Diesel and Biodiesels of Fluorosilicone Rubber Materials Used for Automotive Quick Connector Fuel Line O-Rings and Other Sealing Applications," SAE Paper 2001-01-1124, 2001.

9. Crouse, M., "The Effects of Non-Petroleum Based Fuels on Thermoset Elastomers," SAE Paper 2002-01-0634, 2002.

10. "Viton – Excelling in Modern Automotive Fuel Systems," DuPont Dow Elastomers, 1999.

11. "Fatty Acid Methyl Ester Fuels as a Replacement or Extender for Diesel Fuels: Diesel Fuel Injection Equipment Manufacturers Common Position Statement," Diesel Fuel Injection Equipment Manufacturers (FIE), June 2000.

12. "D 6751: Standard Specification for Biodiesel Fuel (B100) Blend Stock for Distillate Fuels," ASTM International, 2000.

13. "Technical Statement on the Use of Biodiesel Fuel in Compression Ignition Engines," Engine Manufacturers Association, February 2003.

14. Tyson, K. Shaine, "Biodiesel: Handling and Use Guideline," NREL/TP-580-30004, September 2001.

15. “A Comprehensive Analysis of Biodiesel Impacts on Exhaust Emissions: Draft Technical Report,” EPA420-P-02-0001, October 2002.

16. “Determination of Biodiesel Oxidation and Thermal Stability – Final Report,” prepared by SystemLab Services (division of Williams Pipe Line Co.) for National Biodiesel Board, February 12, 1997.

17. Stavinoha, Leo and Steve Howell, “Potential Analytical Methods for Stability Testing of Biodiesel and Biodiesel Blends,” SAE paper 1999-01-3520.

18. Kinast, J.A. (Gas Technology Institute), “Production of Biodiesels from Multiple Feedstocks and Properties of Biodiesels and Biodiesel/Diesel Blends – Final Report/Report 1 in a series of 6”, prepared for the National Renewable Laboratory, March 2003.

19. Mushrush, G.W.(Naval Research Laboratory), et al., “Biodiesel Fuels: The Use of Soy Oil as a Blending Stock for Middle Distillate Petroleum Fuels,” [no date given]

20. Statements in literature and position papers from Caterpillar.

21. Statements in literature and position papers from Cummins.

22. Cummins Service Bulletin – “Fuels for Cummins Engines,” April 22, 2003.

23. Statements in literature and position papers from Detroit Diesel Corporation.

24. Statements in literature and position papers from International Truck and Engine Company.

25. Statements in literature and position papers from John Deere.

Appendix C: Biodiesel Materials Compatibility Testing Results from Literature Review

Sealing/Hose/Fuel Line Materials

Materials found in literature	Specific Reference?	Good or Bad compared to Diesel perf.	% Change Tensile Strength (Biodiesel)	% Change Tensile Strength (Diesel)	% change relative to diesel fuel	Bibliography Source Number	% Biodiesel tested	Temp	Hours
Nitrile rubber	Y	B	n/a	n/a	n/a	14	100	n/a	n/a
Fluorinated rubber (Viton)	Y	G	n/a	n/a	n/a	14	100	n/a	n/a
Nylon	Y	G	n/a	n/a	n/a	14	100	n/a	n/a
Polyurethane (Superthane™)	Y	B	n/a	n/a	n/a	16	100	25	3600
Nitrile Butadiene Rubber (NBR) - medium ACN (33%)	Y	G	1.15	4.07	-2.92	6	100	40	1000
Nitrile Butadiene Rubber (NBR) - medium ACN (35%)	Y	G	-25	-23	-2	6	100	40	168
Nitrile Butadiene Rubber (NBR) - high ACN (40%)	Y	G	7	1	6	6	100	40	168
NBR/PVC (70/30); 33% ACN	Y	B	-27.68	-29.04	1.36	6	100	40	1000
Homo-epichlorohydrin	Y	G	7.57	7.1	0.47	6	100	40	1000
Co-epichlorohydrin	Y	G	-1.45	-4.05	2.6	6	100	40	1000
Ter-epichlorohydrin	Y	G	-21.53	-28.5	6.97	6	100	40	1000
Di-polymer fluorinated (FKM) polymers (65.9% fluorine)	Y	B	-42.98	-44.5	1.52	6	100	40	1000
Ter-polymer fluorinated (FKM) polymers (69.2% fluorine)	Y	G	7.12	6.56	0.56	6	100	40	1000
Fluorosilicone (FVMQ) 75 Durometer (Silastic® brand)	Y	G	-7.8	-3.5	-4.3	12	25	100	168
Fluorosilicone (FVMQ) 75 Durometer (Silastic® brand)	Y	G	-11.89	-3.52	-8.37	12	100	100	168
Fluorosilicone (FVMQ) 75 Durometer (Silastic® brand)	Y	G	-10.59	n/a	n/a	12	25	100	4032
Fluorosilicone (FVMQ) 40 Durometer (Silastic 2840)	Y	G	-23.3	n/a	n/a	12	100	23C	672
	Y	G	-21.8	n/a	n/a	12	100	60C	672
Fluorosilicone (FVMQ) 60 Durometer (Silastic 2860)	Y	G	-17.1	n/a	n/a	12	100	23C	672
	Y	G	-15.04	n/a	n/a	12	100	60C	672
Fluorosilicone (FVMQ) 40 Durometer (Silastic 4-9040)	Y	B	-29.4	n/a	n/a	12	100	23C	672
	Y	G	-20.6	n/a	n/a	12	100	60C	672
Fluorosilicone (FVMQ) 60 Durometer (Silastic 4-9060)	Y	G	-20.6	n/a	n/a	12	100	23C	672
	Y	G	-16.7	n/a	n/a	12	100	60C	672
Fluorosilicone (FVMQ/VQM) Liquid Silicone Rubber 45 Durometer (Dow Corning 5-8601)	Y	G	-51.2	n/a	n/a	12	100	23C	672
	Y	G	-47.4	n/a	n/a	12	100	60C	672
Teflon	Y	G	-7	-11	4	1	20	52C	694
	Y	G	-9	-11	2	1	30	52C	694
Nylon 6/6	Y	B	-5	-13	8	1	20	52C	694
	Y	B	-8	-13	5	1	30	52C	694
Nitrile rubber	Y	B	-34	-27	-7	1	20	52C	694
	Y	B	-51	-27	-24	1	30	52C	694
Viton 401C	Y	G	-15	-28	13	1	20	52C	694
	Y	G	-12	-22	10	1	30	52C	694
Viton GFLT	Y	G	1	2	-1	1	20	52C	694
	Y	G	-7	2	-9	1	30	52C	694
Fluorosilicone	Y	G	0	18	-18	1	20	52C	694
	Y	G	-5	18	-23	1	30	52C	694
Polyurethane	Y	G	-15	-14	-1	1	20	52C	694
	Y	G	-18	-14	-4	1	30	52C	694
Polypropylene	Y	B	-27	-27	0	1	20	52C	694
	Y	B	-26	-27	1	1	30	52C	694

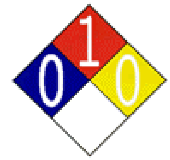
Metals (storage tanks, fuel system)

Materials found in literature	Specific Reference?	Good or Bad?	% Change Tensile Strength	% Change Tensile Strength (Diesel)	relative to diesel fuel	Source #s	% Biodiesel tested	Temp	Hours
Copper (C110)	Y	B	n/a	n/a	n/a	1	100	n/a	n/a
Steel (SAE 1010)	Y	B	n/a	n/a	n/a	1	100	n/a	n/a
Brass (C260)	Y		n/a	n/a	n/a	1	100	n/a	n/a
Aluminum (6061)	Y	B	n/a	n/a	n/a	1	100	n/a	n/a
Cast Aluminum (A319)	Y	B	n/a	n/a	n/a	1	100	n/a	n/a
Bronze (C510)	Y		n/a	n/a	n/a			n/a	n/a
Steel	Y	G??	n/a	n/a	n/a	14	100	n/a	n/a
Aluminum	Y	G??	n/a	n/a	n/a	14	100	n/a	n/a

Appendix D: Material Safety Data Sheet for Biodiesel

BIODIESEL
TM by the National Biodiesel Board

SAMPLE MATERIAL SAFETY DATA SHEET



1. CHEMICAL PRODUCT

General Product Name:	**Biodiesel**
Synonyms:	Methyl Soyate, Rapeseed Methyl Ester (RME), Methyl Tallowate
Product Description:	Methyl esters from lipid sources
CAS Number:	Methyl Soyate: 67784-80-9; RME: 73891-99-3; Methyl Tallowate: 61788-71-2

2. COMPOSITION/INFORMATION ON INGREDIENTS

This product contains no hazardous materials.

3. HAZARDS IDENTIFICATION

Potential Health Effects:

INHALATION:

Negligible unless heated to produce vapors. Vapors or finely misted materials may irritate the mucous membranes and cause irritation, dizziness, and nausea. Remove to fresh air.

EYE CONTACT:

May cause irritation. Irrigate eye with water for at least 15 to 20 minutes. Seek medical attention if symptoms persist.

SKIN CONTACT:

Prolonged or repeated contact is not likely to cause significant skin irritation. Material is sometimes encountered at elevated temperatures. Thermal burns are possible.

INGESTION:

No hazards anticipated from ingestion incidental to industrial exposure.

4. FIRST AID MEASURES

EYES:

Irrigate eyes with a heavy stream of water for at least 15 to 20 minutes.

SKIN:

Wash exposed areas of the body with soap and water.

INHALATION:

Remove from area of exposure, seek medical attention if symptoms persist.

INGESTION:

Give one or two glasses of water to drink. If gastro-intestinal symptoms develop, consult medical personnel. (Never give anything by mouth to an unconscious person.)

5. FIRE FIGHTING MEASURES

Flash Point (Method Used): 130.0° C min (ASTM 93)

Flammability Limits: None known

EXTINGUISHING MEDIA:

Dry chemical, foam, halon, CO_2, water spray (fog). Water stream may splash the burning liquid and spread fire.

SPECIAL FIRE FIGHTING PROCEDURES:

Use water spray to cool drums exposed to fire.

UNUSUAL FIRE AND EXPLOSION HAZARDS:

Oil soaked rags can cause spontaneous combustion if not handled properly. Before disposal, wash rags with soap and water and dry in well ventilated area. Firefighters should use self-contained breathing apparatus to avoid exposure to smoke and vapor.

6. ACCIDENTAL RELEASE MEASURES SPILL CLEAN-UP PROCEDURES

Remove sources of ignition, contain spill to smallest area possible. Stop leak if possible. Pick up small spills with absorbent materials such as paper towels, "Oil Dry", sand or dirt. Recover large spills for salvage or disposal. Wash hard surfaces with safety solvent or detergent to remove remaining oil film. Greasy nature will result in a slippery surface.

---

7. HANDLING AND STORAGE

Store in closed containers between 50°F and 120°F.
Keep away from oxidizing agents, excessive heat, and ignition sources.
Store and use in well ventilated areas.
Do not store or use near heat, spark, or flame, store out of sun.
Do not puncture, drag, or slide this container.
Drum is not a pressure vessel; never use pressure to empty.

---

8. EXPOSURE CONTROL /PERSONAL PROTECTION

RESPIRATORY PROTECTION:

If vapors or mists are generated, wear a NIOSH approved organic vapor/mist respirator.

PROTECTIVE CLOTHING:

Safety glasses, goggles, or face shield recommended to protect eyes from mists or splashing. PVC coated gloves recommended to prevent skin contact.

OTHER PROTECTIVE MEASURES:

Employees must practice good personal hygiene, washing exposed areas of skin several times daily and laundering contaminated clothing before re-use.

---

9. PHYSICAL AND CHEMICAL PROPERTIES

Boiling Point, 760 mm Hg:>200°C
Specific Gravity (H_2O=1): 0.88
Vapor Pressure, mm Hg: <2
Vapor Density, Air=1:>1
Volatiles, % by Volume: <2
Solubility in H_2O, % by Volume: insoluble
Evaporation Rate, Butyl Acetate=1: <1
Appearance and Odor: pale yellow liquid, mild odor

---

10. STABILITY AND REACTIVITY

GENERAL:

This product is stable and hazardous polymerization will not occur.

INCOMPATIBLE MATERIALS AND CONDITIONS TO AVOID:

Strong oxidizing agents

HAZARDOUS DECOMPOSITION PRODUCTS:

Combustion produces carbon monoxide, carbon dioxide along with thick smoke.

---

11. DISPOSAL CONSIDERATIONS

WASTE DISPOSAL:

Waste may be disposed of by a licensed waste disposal company. Contaminated absorbent material may be disposed of in an approved landfill. Follow local, state and federal disposal regulations.

12. TRANSPORT INFORMATION

UN HAZARD CLASS: N/A

NMFC (National Motor Freight Classification):

PROPER SHIPPING NAME: Fatty acid ester
IDENTIFICATION NUMBER: 144920

SHIPPING CLASSIFICATION: 65

---

13. REGULATORY INFORMATION:

OSHA STATUS:

This product is not hazardous under the criteria of the Federal OSHA Hazard Communication Standard 29 CFR 1910.1200. However, thermal processing and decomposition fumes from this product may be hazardous as noted in Sections 2 and 3.

TSCA STATUS:

This product is listed on TSCA.

CERCLA (Comprehensive Response Compensation and Liability Act):

NOT reportable.

SARA TITLE III (Superfund Amendments and Reauthorization Act):

Section 312 Extremely Hazardous Substances:

None

Section 311/312 Hazard Categories:

Non-hazardous under Section 311/312

Section 313 Toxic Chemicals:

None

RCRA STATUS:

If discarded in its purchased form, this product would not be a hazardous waste either by listing or by characteristic. However, under RCRA, it is the responsibility of the product user to determine at the time of disposal, whether a material containing the product or derived from the product should be classified as a hazardous waste,
(40 CFR 261.20-24)

CALIFORNIA PROPOSITION 65:

The following statement is made in order to comply with the California Safe Drinking Water and Toxic Enforcement Act of 1986. This product contains no chemicals known to the state of California to cause cancer.

---

14. OTHER INFORMATION:

This information relates only to the specific material designated and may not be valid for such material used in combination with any other materials or in any other process. Such information is to the best of the company’s knowledge and believed accurate and reliable as of the date indicated. However, no representation, warranty or guarantee of any kind, express or implied, is made as to its accuracy, reliability or completeness and we assume no responsibility for any loss, damage or expense, direct or consequential, arising out of use. It is the user’s responsibility to satisfy himself as to the suitableness and completeness of such information for his own particular use.

Appendix E: EPA MOBILE6 Vehicle Emission Factors

2003-2010 Aging Current Fleet

Aging Current Fleet Emission Rates

CY	Pol Name	LDGV	LDGT1	LDGT3	LDGT4	HDGV8A	HDDV8A	URB BUS	LDDT34
2003	VMT	0.034	0.005	0.074	0.222	0.002	0.112	0.538	0.013
2003	Total PM	0.028	0.033	0.030	0.029	0.100	0.412	1.021	0.150
2003	SO2	0.0588	0.0736	0.0977	0.0977	0.2039	0.4866	0.7503	0.1869
2003	NH3	0.1017	0.0961	0.1011	0.1016	0.0451	0.027	0.027	0.0068
2003	MPG	24.00	19.00	14.50	14.50	7.00	6.50	4.20	17.00
2003	VMT	0.034	0.005	0.0741	0.2224	0.0016	0.1115	0.5384	0.013
2003	VOC	1.611	3.512	1.705	1.586	2.094	0.57	0.737	0.649
2003	CO	17.251	32.493	19.424	18.963	15.087	3.118	4.629	1.098
2003	NOX	1.337	2.151	1.597	2.065	7.128	18.002	20.641	1.431
2003	CO2	354.1	423.8	592.4	593.3	1239	1557.3	2402.4	593.8
2003	Total Evap	0.871	1.896	0.794	0.662	1.321	0	0	0
	Total VOC	2.482	5.408	2.499	2.248	3.415	0.57	0.737	0.649
		Cars	Pick Up Compact	P'up LG/ Minivan (Gas)	Van/SUV (Gas)	Truck MD-HD (Gas)	Truck MD-HD (Diesel)	Bus (Diesel)	Truck LD + Van (Diesel)

Aging Current Fleet Emission Rates

CY	Pol Name	LDGV	LDGT1	LDGT3	LDGT4	HDGV8A	HDDV8A	URB BUS	LDDT34
2004	VMT	0.034	0.005	0.072	0.230	0.000	0.113	0.538	0.008
2004	Total PM	0.0262	0.0299	0.0276	0.0272	0.0998	0.4068	1.0234	0.1324
2004	SO2	0.0275	0.0344	0.0456	0.0456	0.1378	0.4865	0.7503	0.1869
2004	NH3	0.1017	0.0961	0.1011	0.1016	0.0451	0.027	0.027	0.0068
2004	MPG	24	19	14.5	14.5	7.0000	6.5	4.2	17
2004	VMT	0.034	0.005	0.0723	0.23	0.0016	0.113	0.5381	0.0075
2004	VOC	1.741	3.909	1.838	1.633	1.7995	0.577	0.738	0.587
2004	CO	16.504	32.653	19.493	18.467	13.9215	3.135	4.63	0.996
2004	NOX	1.364	2.202	1.677	2.132	6.9280	17.299	20.641	1.367
2004	CO2	352.6	420.8	589.4	591.2	1233	1556.9	2402.4	594.2
2004	Total Evap	1.027	2.252	0.927	0.742	1.1385	0	0	0
	Total VOC	2.768	6.161	2.765	2.375	2.938	0.577	0.738	0.587
		Cars	Pick Up Compact	P'up LG/ Minivan (Gas)	Van/SUV (Gas)	Truck MD-HD (Gas)	Truck MD-HD (Diesel)	Bus (Diesel)	Truck LD + Van (Diesel)

Aging Current Fleet Emission Rates

CY	Pol Name	LDGV	LDGT1	LDGT3	LDGT4	HDGV8A	HDDV8A	URB BUS	LDDT34
2005	VMT	0.034	0.005	0.072	0.227	0.002	0.112	0.538	0.011
2005	Total PM	0.0259	0.0292	0.0271	0.0267	0.0994	0.4122	1.0258	0.1351
2005	SO2	0.0209	0.0261	0.0347	0.0347	0.0716	0.4868	0.7503	0.1869
2005	NH3	0.1017	0.0962	0.1011	0.1016	0.0451	0.027	0.027	0.0068
2005	MPG	24	19	14.5	14.5	7.1	6.5	4.2	17
2005	VMT	0.034	0.005	0.0721	0.2265	0.0015	0.1116	0.5382	0.0112
2005	VOC	1.963	4.402	2.027	1.808	1.505	0.587	0.74	0.699
2005	CO	17.112	33.903	20.401	19.437	12.756	3.196	4.632	1.151
2005	NOX	1.437	2.285	1.787	2.265	6.728	17.308	20.641	1.474
2005	CO2	351.1	417.6	587.2	588.8	1226.4	1557.7	2402.4	593.5
2005	Total Evap	1.212	2.659	1.063	0.856	0.956	0	0	0
	Total VOC	3.175	7.061	3.09	2.664	2.461	0.587	0.74	0.699
		Cars	Pick Up Compact	P'up LG/ Minivan (Gas)	Van/SUV (Gas)	Truck MD-HD (Gas)	Truck MD-HD (Diesel)	Bus (Diesel)	Truck LD + Van (Diesel)

2003-2010 Aging Current Fleet

Aging Current Fleet Emission Rates									
CY	**Pol Name**	**LDGV**	**LDGT1**	**LDGT3**	**LDGT4**	**HDGV8A**	**HDDV8A**	**URB BUS**	**LDDT34**
2006	VMT	0.034	0.005	0.073	0.230	0.001	0.112	0.538	0.006
2006	Tire	0.008	0.008	0.008	0.008	0.036	0.036	0.012	0.008
2006	Total PM	0.0252	0.0279	0.0261	0.0257	0.0988	0.411	1.0281	0.1303
2006	SO2	0.0075	0.0094	0.0124	0.0124	0.0257	0.4867	0.7503	0.1869
2006	NH3	0.1017	0.0963	0.1011	0.1016	0.0451	0.027	0.027	0.0068
2006	MPG	24	19	14.5	14.5	7.1	6.5	4.2	17
2006	VMT	0.034	0.005	0.0734	0.2303	0.0011	0.1119	0.5381	0.0062
2006	VOC	2.191	4.9	2.222	1.951	1.295	0.593	0.741	0.658
2006	CO	16.943	34.134	20.603	19.55	12.36	3.223	4.633	1.045
2006	NOX	1.482	2.326	1.855	2.349	5.559	17.39	20.641	1.444
2006	CO2	349.6	414.2	585	586.7	1226.4	1557.4	2402.4	593.8
2006	Total Evap	1.424	3.115	1.235	0.976	0.775	0	0	0
	Total VOC	3.615	8.015	3.457	2.927	2.07	0.593	0.741	0.658
		Cars	Pick Up Compact	P'up LG/ Minivan (Gas)	Van/SUV (Gas)	Truck MD-HD (Gas)	Truck MD-HD (Diesel)	Bus (Diesel)	Truck LD + Van (Diesel)

Aging Current Fleet Emission Rates									
CY	**Pol Name**	**LDGV**	**LDGT1**	**LDGT3**	**LDGT4**	**HDGV8A**	**HDDV8A**	**URB BUS**	**LDDT34**
2007	VMT	0.034	0.005	0.074	0.232	0.002	0.111	0.538	0.004
2007	Total PM	0.0252	0.0278	0.0261	0.0257	0.0988	0.4407	1.0304	0.1296
2007	SO2	0.0075	0.0094	0.0124	0.0124	0.0257	0.4883	0.7503	0.1869
2007	NH3	0.1017	0.0964	0.1011	0.1016	0.0451	0.027	0.027	0.0068
2007	MPG	24	19	14.5	14.5	7.1	6.5	4.2	17
2007	VMT	0.034	0.005	0.0742	0.232	0.0023	0.1107	0.538	0.0038
2007	VOC	2.48	5.527	2.469	2.174	1.243	0.613	0.742	0.694
2007	CO	17.861	36.153	21.881	20.766	12.36	3.403	4.635	1.085
2007	NOX	1.563	2.433	1.971	2.487	5.559	17.462	20.641	1.474
2007	CO2	348.1	410.5	582.7	584.6	1226.4	1562.2	2402.4	593.6
2007	Total Evap	1.66	3.621	1.407	1.121	0.724	0	0	0
	Total VOC	4.14	9.148	3.876	3.295	1.967	0.613	0.742	0.694
		Cars	Pick Up Compact	P'up LG/ Minivan (Gas)	Van/SUV (Gas)	Truck MD-HD (Gas)	Truck MD-HD (Diesel)	Bus (Diesel)	Truck LD + Van (Diesel)

Aging Current Fleet Emission Rates									
CY	**Pol Name**	**LDGV**	**LDGT1**	**LDGT3**	**LDGT4**	**HDGV8A**	**HDDV8A**	**URB BUS**	**LDDT34**
2008	VMT	0.034	0.005	0.075	0.232	0.001	0.112	0.538	0.003
2008	Total PM	0.0251	0.0277	0.026	0.0257	0.1008	0.4347	1.0325	0.1296
2008	SO2	0.0068	0.0085	0.0113	0.0113	0.0231	0.488	0.7503	0.1869
2008	NH3	0.1017	0.0964	0.1011	0.1016	0.0451	0.027	0.027	0.0068
2008	MPG	24	19	14.5	14.5	7.1	6.5	4.2	17
2008	VMT	0.034	0.005	0.0752	0.232	0.0008	0.1122	0.538	0.0028
2008	VOC	2.788	6.206	2.736	2.422	1.24	0.615	0.744	0.667
2008	CO	18.669	38.209	23.086	21.908	12.324	3.396	4.636	1.051
2008	NOX	1.64	2.541	2.083	2.612	5.559	17.367	20.641	1.451
2008	CO2	346.7	406.5	580.3	582.4	1226.4	1561.1	2402.3	593.8
2008	Total Evap	1.916	4.173	1.6	1.291	0.724	0	0	0
	Total VOC	4.704	10.379	4.336	3.713	1.964	0.615	0.744	0.667
		Cars	Pick Up Compact	P'up LG/ Minivan (Gas)	Van/SUV (Gas)	Truck MD-HD (Gas)	Truck MD-HD (Diesel)	Bus (Diesel)	Truck LD + Van (Diesel)

2003-2010 Aging Current Fleet

Aging Current Fleet Emission Rates									
CY	**Pol Name**	**LDGV**	**LDGT1**	**LDGT3**	**LDGT4**	**HDGV8A**	**HDDV8A**	**URB BUS**	**LDDT34**
2009	VMT	0.034	0.005	0.075	0.232	0.001	0.113	0.538	0.003
2009	Total PM	0.0251	0.0277	0.0260	0.0257	0.1008	0.4794	1.0347	0.1296
2009	SO2	0.0068	0.0085	0.0113	0.0113	0.0231	0.4905	0.7503	0.1869
2009	NH3	0.1017	0.0965	0.1011	0.1016	0.0451	0.027	0.027	0.0068
2009	MPG	24	19	14.5	14.5	7	6.4	4.2	17
2009	VMT	0.034	0.005	0.0747	0.232	0.0008	0.113	0.538	0.0033
2009	VOC	3.113	6.95	3.042	2.695	1.24	0.643	0.745	0.764
2009	CO	19.535	40.609	24.352	23.114	12.324	3.658	4.638	1.166
2009	NOX	1.719	2.665	2.186	2.734	5.559	18.241	20.641	1.534
2009	CO2	345.3	402.2	578.1	580.3	1226.4	1568.4	2402.3	593.2
2009	Total Evap	2.187	4.771	1.827	1.48	0.724	0	0	0
	Total VOC	5.3	11.721	4.869	4.175	1.964	0.643	0.745	0.764
		Cars	Pick Up Compact	P'up LG/ Minivan (Gas)	Van/SUV (Gas)	Truck MD-HD (Gas)	Truck MD-HD (Diesel)	Bus (Diesel)	Truck LD + Van (Diesel)

Aging Current Fleet Emission Rates									
CY	**Pol Name**	**LDGV**	**LDGT1**	**LDGT3**	**LDGT4**	**HDGV8A**	**HDDV8A**	**URB BUS**	**LDDT34**
2010	VMT	0.034	0.005	0.078	0.232	0.001	0.113	0.538	0.000
2010	Total PM	0.0251	0.0276	0.0259	0.0257	0.1008	0.4835	1.0367	0.1296
2010	SO2	0.0068	0.0085	0.0113	0.0113	0.0231	0.4905	0.7503	0.1869
2010	NH3	0.1017	0.0968	0.1014	0.1016	0.0451	0.027	0.027	0.0068
2010	MPG	24	19.1	14.5	14.5	7	6.4	4.2	17
2010	VMT	0.034	0.005	0.0776	0.232	0.0008	0.113	0.538	0.0004
2010	VOC	3.449	7.712	3.253	2.987	1.24	0.643	0.746	0.768
2010	CO	20.361	42.131	25.119	24.306	12.324	3.712	4.639	1.171
2010	NOX	1.795	2.796	2.281	2.848	5.559	18.273	20.641	1.538
2010	CO2	343.9	397.7	576.9	578.1	1226.4	1568.3	2402.3	593.2
2010	Total Evap	2.466	5.405	1.986	1.687	0.724	0	0	0
	Total VOC	5.915	13.117	5.239	4.674	1.964	0.643	0.746	0.768
		Cars	Pick Up Compact	P'up LG/ Minivan (Gas)	Van/SUV (Gas)	Truck MD-HD & Maint. (Gas)	Truck MD-HD & Maint. (Diesel)	Bus (Diesel)	Truck LD + Van (Diesel)

2003-2010 New Model Years

	New Model Year Emission Rates								
CY	**Pol Name**	**LDGV**	**LDGT1**	**LDGT3**	**LDGT4**	**HDGV8A**	**HDDV8A**	**URB BUS**	**LDDT34**
2003	VMT	0.034	0.005	0.078	0.232	0	0.113	0.538	0.3101
2003	Lead	0	0	0	0	0	NA	NA	NA
2003	GASPM	0.0042	0.0042	0.0042	0.0042	0	NA	NA	NA
2003	ECARBON	NA	NA	NA	NA	NA	0.1142	0.0764	0.0407
2003	OCARBON	NA	NA	NA	NA	NA	0.0897	0.06	0.0586
2003	SO4	0.0025	0.004	0.004	0.004	0	0.0336	0.0507	0.0098
2003	Brake	0.0125	0.0125	0.0125	0.0125	0	0.0125	0.0125	0.0125
2003	Tire	0.008	0.008	0.008	0.008	0	0.036	0.012	0.008
2003	Total PM	0.0272	0.0287	0.0287	0.0287	0	0.286	0.2116	0.1296
2003	SO2	0.0587	0.0762	0.0996	0.0996	0	0.4797	0.725	0.1869
2003	NH3	0.1017	0.1017	0.1017	0.1017	0	0.027	0.027	0.0068
2003	MPG	24.1	18.5	14.2	14.2	0	6.6	4.4	17
2003	VMT	0.034	0.005	0.078	0.232	0	0.113	0.538	0.3101
2003	VOC	0.168	0.152	0.555	0.598	0	0.431	0.226	0.27
2003	CO	5.617	5.55	4.092	4.385	0	2.191	3.136	0.643
2003	NOX	0.327	0.317	0.524	0.785	0	6.69	13.415	1.024
2003	CO2	365.2	476.8	620.9	620.5	0	1537.8	2326.6	596.2
2003	Hot Soak	0.015	0.009	0.009	0.009	0	0	0	0
2003	Diurnal	0.003	0.002	0.002	0.002	0	0	0	0
2003	Resting	0.01	0.008	0.007	0.007	0	0	0	0
2003	Running	0.04	0.034	0.034	0.034	0	0	0	0
2003	Crankcase	0.001	0.002	0.002	0.002	0	0	0	0
2003	Refueling	0.009	0.014	0.271	0.271	0	NA	NA	NA
2003	Total Evap	0.078	0.07	0.325	0.325	0	0	0	0
	Total VOC	0.246	0.222	0.88	0.923	0	0.431	0.226	0.27
		Cars	Pick Up Compact	P'up LG/ Minivan (Gas)	Van/SUV (Gas)	Truck MD-HD & Maint. (Gas)	Truck MD-HD & Maint. (Diesel)	Bus (Diesel)	P'up LG + Van (Diesel)

	New Model Year Emission Rates								
CY	**Pol Name**	**LDGV**	**LDGT1**	**LDGT3**	**LDGT4**	**HDGV8A**	**HDDV8A**	**URB BUS**	**LDDT34**
2004	VMT	0.034	0.005	0.078	0.232	0	0.113	0.538	0.3101
2004	Lead	0	0	0	0	0	NA	NA	NA
2004	GASPM	0.0039	0.0037	0.0037	0.0037	0	NA	NA	NA
2004	ECARBON	NA	NA	NA	NA	NA	0.1142	0.0764	0.0153
2004	OCARBON	NA	NA	NA	NA	NA	0.0897	0.06	0.022
2004	SO4	0.0012	0.0019	0.0019	0.0019	0	0.0336	0.0507	0.0098
2004	Brake	0.0125	0.0125	0.0125	0.0125	0	0.0125	0.0125	0.0125
2004	Tire	0.008	0.008	0.008	0.008	0	0.036	0.012	0.008
2004	Total PM	0.0256	0.0261	0.0261	0.0261	0	0.286	0.2116	0.0676
2004	SO2	0.0274	0.0356	0.0465	0.0465	0	0.4797	0.725	0.1869
2004	NH3	0.1017	0.1017	0.1017	0.1017	0	0.027	0.027	0.0068
2004	MPG	24.1	18.5	14.2	14.2	0	6.6	4.4	17
2004	VMT	0.034	0.005	0.078	0.232	0	0.113	0.538	0.3101
2004	VOC	0.138	0.126	0.313	0.34	0	0.29	0.237	0.094
2004	CO	3.601	3.392	3.204	3.426	0	2.191	3.136	0.387
2004	NOX	0.176	0.17	0.242	0.322	0	5.887	9.494	0.268
2004	CO2	365.2	476.8	621.5	621.2	0	1538.4	2326.6	597.5
2004	Hot Soak	0.013	0.009	0.009	0.009	0	0	0	0
2004	Diurnal	0.003	0.002	0.002	0.002	0	0	0	0
2004	Resting	0.008	0.006	0.007	0.007	0	0	0	0
2004	Running	0.04	0.034	0.034	0.034	0	0	0	0
2004	Crankcase	0.001	0.002	0.002	0.002	0	0	0	0
2004	Refueling	0.009	0.014	0.17	0.17	0	NA	NA	NA
2004	Total Evap	0.074	0.068	0.225	0.225	0	0	0	0
2004	Total VOC	0.212	0.194	0.538	0.565	0	0.29	0.237	0.094
		Cars	Pick Up Compact	P'up LG/ Minivan (Gas)	Van/SUV (Gas)	Truck MD-HD & Maint. (Gas)	Truck MD-HD & Maint. (Diesel)	Bus (Diesel)	Truck LD + Van (Diesel)

2003-2010 New Model Years

	New Model Year Emission Rates								
CY	**Pol Name**	**LDGV**	**LDGT1**	**LDGT3**	**LDGT4**	**HDGV8A**	**HDDV8A**	**URB BUS**	**LDDT34**
2005	VMT	0.034	0.005	0.078	0.232	0	0.113	0.538	0.3101
2005	Lead	0	0	0	0	0	NA	NA	NA
2005	GASPM	0.0039	0.0037	0.0037	0.0037	0	NA	NA	NA
2005	ECARBON	NA	NA	NA	NA	NA	0.1142	0.0764	0.0077
2005	OCARBON	NA	NA	NA	NA	NA	0.0897	0.06	0.0111
2005	SO4	0.0009	0.0014	0.0014	0.0014	0	0.0336	0.0507	0.0098
2005	Brake	0.0125	0.0125	0.0125	0.0125	0	0.0125	0.0125	0.0125
2005	Tire	0.008	0.008	0.008	0.008	0	0.036	0.012	0.008
2005	Total PM	0.0253	0.0256	0.0256	0.0256	0	0.286	0.2116	0.0491
2005	SO2	0.0208	0.0271	0.0354	0.0354	0	0.4797	0.725	0.1869
2005	NH3	0.1017	0.1017	0.1017	0.1017	0	0.027	0.027	0.0068
2005	MPG	24.1	18.5	14.2	14.2	0	6.6	4.4	17
2005	VMT	0.034	0.005	0.078	0.232	0	0.113	0.538	0.3101
2005	VOC	0.131	0.121	0.202	0.236	0	0.29	0.237	0.094
2005	CO	3.376	3.182	2.818	3.276	0	2.191	3.136	0.387
2005	NOX	0.104	0.098	0.167	0.312	0	5.887	9.494	0.268
2005	CO2	365.2	476.8	621.7	621.2	0	1538.4	2326.6	597.5
2005	Hot Soak	0.012	0.008	0.009	0.009	0	0	0	0
2005	Diurnal	0.002	0.002	0.002	0.002	0	0	0	0
2005	Resting	0.007	0.005	0.007	0.007	0	0	0	0
2005	Running	0.04	0.034	0.034	0.034	0	0	0	0
2005	Crankcase	0.001	0.002	0.002	0.002	0	0	0	0
2005	Refueling	0.009	0.014	0.069	0.069	0	NA	NA	NA
2005	Total Evap	0.071	0.066	0.124	0.124	0	0	0	0
	Total VOC	0.202	0.187	0.326	0.36	0	0.29	0.237	0.094
		Cars	Pick Up Compact	P'up LG/ Minivan (Gas)	Van/SUV (Gas)	Truck MD-HD & Maint. (Gas)	Truck MD-HD & Maint. (Diesel)	Bus (Diesel)	Truck LD + Van (Diesel)

	New Model Year Emission Rates								
CY	**Pol Name**	**LDGV**	**LDGT1**	**LDGT3**	**LDGT4**	**HDGV8A**	**HDDV8A**	**URB BUS**	**LDDT34**
2006	VMT	0.034	0.005	0.078	0.232	0	0.113	0.538	0.3101
2006	Lead	0	0	0	0	0	NA	NA	NA
2006	GASPM	0.0039	0.0037	0.0037	0.0037	0	NA	NA	NA
2006	ECARBON	NA	NA	NA	NA	NA	0.1142	0.0764	0.0037
2006	OCARBON	NA	NA	NA	NA	NA	0.0897	0.06	0.0053
2006	SO4	0.0003	0.0005	0.0005	0.0005	0	0.0336	0.0507	0.0098
2006	Brake	0.0125	0.0125	0.0125	0.0125	0	0.0125	0.0125	0.0125
2006	Tire	0.008	0.008	0.008	0.008	0	0.036	0.012	0.008
2006	Total PM	0.0247	0.0247	0.0247	0.0247	0	0.286	0.2116	0.0393
2006	SO2	0.0075	0.0097	0.0127	0.0127	0	0.4797	0.725	0.1869
2006	NH3	0.1017	0.1017	0.1017	0.1017	0	0.027	0.027	0.0068
2006	MPG	24.1	18.5	14.2	14.2	0	6.6	4.4	17
2006	VMT	0.034	0.005	0.078	0.232	0	0.113	0.538	0.3101
2006	VOC	0.114	0.106	0.136	0.161	0	0.29	0.237	0.087
2006	CO	2.297	2.176	2.053	2.428	0	2.191	3.136	0.368
2006	NOX	0.045	0.041	0.098	0.224	0	5.887	9.494	0.229
2006	CO2	365.2	476.8	621.9	621.4	0	1538.4	2326.6	597.6
2006	Hot Soak	0.01	0.007	0.009	0.009	0	0	0	0
2006	Diurnal	0.002	0.001	0.002	0.002	0	0	0	0
2006	Resting	0.005	0.004	0.007	0.007	0	0	0	0
2006	Running	0.04	0.034	0.034	0.034	0	0	0	0
2006	Crankcase	0.001	0.002	0.002	0.002	0	0	0	0
2006	Refueling	0.009	0.014	0.019	0.019	0	NA	NA	NA
2006	Total Evap	0.067	0.064	0.073	0.073	0	0	0	0
	Total VOC	0.181	0.17	0.209	0.234	0	0.29	0.237	0.087
		Cars	Pick Up Compact	P'up LG/ Minivan (Gas)	Van/SUV (Gas)	Truck MD-HD & Maint. (Gas)	Truck MD-HD & Maint. (Diesel)	Bus (Diesel)	Truck LD + Van (Diesel)

2003-2010 New Model Years

CY	Pol Name	LDGV	LDGT1	LDGT3	LDGT4	HDGV8A	HDDV8A	URB BUS	LDDT34
	New Model Year Emission Rates								
2007	VMT	0.034	0.005	0.078	0.232	0	0.113	0.538	0.3101
2007	Lead	0	0	0	0	0	NA	NA	NA
2007	GASPM	0.0039	0.0037	0.0037	0.0037	0	NA	NA	NA
2007	ECARBON	NA	NA	NA	NA	NA	0.0139	0.0203	0.0037
2007	OCARBON	NA	NA	NA	NA	NA	0.011	0.0159	0.0053
2007	SO4	0.0003	0.0005	0.0005	0.0005	0	0.0336	0.0507	0.0098
2007	Brake	0.0125	0.0125	0.0125	0.0125	0	0.0125	0.0125	0.0125
2007	Tire	0.008	0.008	0.008	0.008	0	0.036	0.012	0.008
2007	Total PM	0.0247	0.0247	0.0247	0.0247	0	0.107	0.1114	0.0393
2007	SO2	0.0075	0.0097	0.0127	0.0127	0	0.4797	0.725	0.1869
2007	NH3	0.1017	0.1017	0.1017	0.1017	0	0.027	0.027	0.0068
2007	MPG	24.1	18.5	14.2	14.2	0	6.6	4.4	17
2007	VMT	0.034	0.005	0.078	0.232	0	0.113	0.538	0.3101
2007	VOC	0.098	0.093	0.136	0.136	0	0.262	0.237	0.06
2007	CO	1.69	1.613	2.053	2.035	0	0.244	0.326	0.299
2007	NOX	0.034	0.03	0.098	0.108	0	3.149	5.166	0.094
2007	CO2	366	477.5	621.9	622	0	1542.7	2332.6	597.8
2007	Hot Soak	0.008	0.007	0.009	0.009	0	0	0	0
2007	Diurnal	0.001	0.001	0.002	0.002	0	0	0	0
2007	Resting	0.004	0.003	0.007	0.007	0	0	0	0
2007	Running	0.04	0.034	0.034	0.034	0	0	0	0
2007	Crankcase	0.001	0.002	0.002	0.002	0	0	0	0
2007	Refueling	0.009	0.014	0.019	0.019	0	NA	NA	NA
2007	Total Evap	0.063	0.062	0.073	0.073	0	0	0	0
	Total VOC	0.161	0.155	0.209	0.209	0	0.262	0.237	0.06
		Cars	Pick Up Compact	P'up LG/ Minivan (Gas)	Van/SUV (Gas)	Truck MD-HD & Maint. (Gas)	Truck MD-HD & Maint. (Diesel)	Bus (Diesel)	Truck LD + Van (Diesel)

CY	Pol Name	LDGV	LDGT1	LDGT3	LDGT4	HDGV8A	HDDV8A	URB BUS	LDDT34
	New Model Year Emission Rates								
2008	VMT	0.034	0.005	0.078	0.232	0	0.113	0.538	0.3101
2008	Lead	0	0	0	0	0	NA	NA	NA
2008	GASPM	0.0039	0.0037	0.0037	0.0037	0	NA	NA	NA
2008	ECARBON	NA	NA	NA	NA	NA	0.0139	0.0203	0.0037
2008	OCARBON	NA	NA	NA	NA	NA	0.011	0.0159	0.0053
2008	SO4	0.0003	0.0005	0.0005	0.0005	0	0.0336	0.0507	0.0098
2008	Brake	0.0125	0.0125	0.0125	0.0125	0	0.0125	0.0125	0.0125
2008	Tire	0.008	0.008	0.008	0.008	0	0.036	0.012	0.008
2008	Total PM	0.0247	0.0247	0.0247	0.0247	0	0.107	0.1114	0.0393
2008	SO2	0.0068	0.0088	0.0115	0.0115	0	0.4797	0.725	0.1869
2008	NH3	0.1017	0.1017	0.1017	0.1017	0	0.027	0.027	0.0068
2008	MPG	24.1	18.5	14.2	14.2	0	6.6	4.4	17
2008	VMT	0.034	0.005	0.078	0.232	0	0.113	0.538	0.3101
2008	VOC	0.097	0.092	0.115	0.132	0	0.262	0.237	0.06
2008	CO	1.632	1.559	2.007	1.99	0	0.244	0.326	0.299
2008	NOX	0.033	0.029	0.059	0.106	0	3.149	5.166	0.094
2008	CO2	366	477.5	622	622	0	1542.7	2332.6	597.8
2008	Hot Soak	0.008	0.007	0.008	0.008	0	0	0	0
2008	Diurnal	0.001	0.001	0.002	0.002	0	0	0	0
2008	Resting	0.004	0.003	0.005	0.005	0	0	0	0
2008	Running	0.04	0.034	0.034	0.034	0	0	0	0
2008	Crankcase	0.001	0.002	0.002	0.002	0	0	0	0
2008	Refueling	0.009	0.014	0.019	0.019	0	NA	NA	NA
2008	Total Evap	0.063	0.062	0.07	0.07	0	0	0	0
	Total VOC	0.16	0.154	0.185	0.202	0	0.262	0.237	0.06
		Cars	Pick Up Compact	P'up LG/ Minivan (Gas)	Van/SUV (Gas)	Truck MD-HD & Maint. (Gas)	Truck MD-HD & Maint. (Diesel)	Bus (Diesel)	Truck LD + Van (Diesel)

2003-2010 New Model Years

	New Model Year Emission Rates								
CY	**Pol Name**	**LDGV**	**LDGT1**	**LDGT3**	**LDGT4**	**HDGV8A**	**HDDV8A**	**URB BUS**	**LDDT34**
2009	VMT	0.034	0.005	0.078	0.232	0	0.113	0.538	0.3101
2009	Lead	0	0	0	0	0	NA	NA	NA
2009	GASPM	0.0039	0.0037	0.0037	0.0037	0	NA	NA	NA
2009	ECARBON	NA	NA	NA	NA	NA	0.0139	0.0203	0.0037
2009	OCARBON	NA	NA	NA	NA	NA	0.011	0.0159	0.0053
2009	SO4	0.0003	0.0005	0.0005	0.0005	0	0.0336	0.0507	0.0098
2009	Brake	0.0125	0.0125	0.0125	0.0125	0	0.0125	0.0125	0.0125
2009	Tire	0.008	0.008	0.008	0.008	0	0.036	0.012	0.008
2009	Total PM	0.0247	0.0247	0.0247	0.0247	0	0.107	0.1114	0.0393
2009	SO2	0.0068	0.0088	0.0115	0.0115	0	0.4797	0.725	0.1869
2009	NH3	0.1017	0.1017	0.1017	0.1017	0	0.027	0.027	0.0068
2009	MPG	24.1	18.5	14.2	14.2	0	6.6	4.4	17
2009	VMT	0.034	0.005	0.078	0.232	0	0.113	0.538	0.3101
2009	VOC	0.088	0.084	0.109	0.117	0	0.262	0.237	0.048
2009	CO	1.34	1.287	2.007	1.99	0	0.244	0.326	0.299
2009	NOX	0.026	0.022	0.059	0.106	0	3.149	5.166	0.094
2009	CO2	366.4	477.9	622	622	0	1542.7	2332.6	597.9
2009	Hot Soak	0.008	0.007	0.007	0.007	0	0	0	0
2009	Diurnal	0.001	0.001	0.001	0.001	0	0	0	0
2009	Resting	0.004	0.003	0.004	0.004	0	0	0	0
2009	Running	0.04	0.034	0.034	0.034	0	0	0	0
2009	Crankcase	0.001	0.002	0.002	0.002	0	0	0	0
2009	Refueling	0.009	0.014	0.019	0.019	0	NA	NA	NA
2009	Total Evap	0.063	0.062	0.067	0.067	0	0	0	0
	Total VOC	0.151	0.146	0.176	0.184	0	0.262	0.237	0.048
		Cars	Pick Up Compact	P'up LG/ Minivan (Gas)	Van/SUV (Gas)	Truck MD-HD & Maint. (Gas)	Truck MD-HD & Maint. (Diesel)	Bus (Diesel)	Truck LD + Van (Diesel)

	New Model Year Emission Rates								
CY	**Pol Name**	**LDGV**	**LDGT1**	**LDGT3**	**LDGT4**	**HDGV8A**	**HDDV8A**	**URB BUS**	**LDDT34**
2010	VMT	0.034	0.005	0.078	0.232	0	0.113	0.538	0.3101
2010	Lead	0	0	0	0	0	NA	NA	NA
2010	GASPM	0.0039	0.0037	0.0037	0.0037	0	NA	NA	NA
2010	ECARBON	NA	NA	NA	NA	NA	0.0139	0.0203	0.0037
2010	OCARBON	NA	NA	NA	NA	NA	0.011	0.0159	0.0053
2010	SO4	0.0003	0.0005	0.0005	0.0005	0	0.0336	0.0507	0.0098
2010	Brake	0.0125	0.0125	0.0125	0.0125	0	0.0125	0.0125	0.0125
2010	Tire	0.008	0.008	0.008	0.008	0	0.036	0.012	0.008
2010	Total PM	0.0247	0.0247	0.0247	0.0247	0	0.107	0.1114	0.0393
2010	SO2	0.0068	0.0088	0.0115	0.0115	0	0.4797	0.725	0.1869
2010	NH3	0.1017	0.1017	0.1017	0.1017	0	0.027	0.027	0.0068
2010	MPG	24.1	18.5	14.2	14.2	0	6.6	4.4	17
2010	VMT	0.034	0.005	0.078	0.232	0	0.113	0.538	0.3101
2010	VOC	0.088	0.084	0.109	0.117	0	0.262	0.237	0.048
2010	CO	1.34	1.287	2.007	1.99	0	0.244	0.326	0.299
2010	NOX	0.026	0.022	0.059	0.106	0	0.531	0.774	0.094
2010	CO2	366.4	477.9	622	622	0	1542.7	2332.6	597.9
2010	Hot Soak	0.008	0.007	0.007	0.007	0	0	0	0
2010	Diurnal	0.001	0.001	0.001	0.001	0	0	0	0
2010	Resting	0.004	0.003	0.004	0.004	0	0	0	0
2010	Running	0.04	0.034	0.034	0.034	0	0	0	0
2010	Crankcase	0.001	0.002	0.002	0.002	0	0	0	0
2010	Refueling	0.009	0.014	0.019	0.019	0	NA	NA	NA
2010	Total Evap	0.063	0.062	0.067	0.067	0	0	0	0
	Total VOC	0.151	0.146	0.176	0.184	0	0.262	0.237	0.048
		Cars	Pick Up Compact	P'up LG/ Minivan (Gas)	Van/SUV (Gas)	Truck MD-HD & Maint. (Gas)	Truck MD-HD & Maint. (Diesel)	Bus (Diesel)	Truck LD + Van (Diesel)

Appendix F: Diesel Fuel Injection Equipment Manufacturers Common Position Statement

Fatty Acid Methyl Ester Fuels as a Replacement or Extender for Diesel Fuels

Diesel Fuel Injection Equipment Manufacturers Common Position Statement

Background:

Diesel Fuel Injection Equipment (FIE) manufacturers fully support the development of alternative sources of fuel for compression ignition engines.

In Europe and in the United States, fuel resources such as Rape Methyl Ester (RME) and Soybean Methyl Ester (SOME), collectively known as Fatty Acid Methyl Esters (FAME) are being used as alternatives & extenders for mineral oil derived fuels.

The introduction of any change in fuel composition needs to be fully assessed by those responsible, before these fuels are made available to the public. The need for thorough evaluation has been highlighted in recent years with the changes made to remove sulphur from mineral oil diesel fuels, which caused excessive wear and failure of rotary fuel injection equipment. In this case, release of the fuels took place before a suitable lubricity standard was in place to protect end-users from product failures.

The FIE manufacturers are aware of issues peculiar to fatty acid methyl ester fuels and are active in the generation of Standards for these fuels to protect the end-users of their products from potential premature failure. Biodiesels must conform to such Standards to be of acceptable quality, just as mineral oils do at present.

<u>To date, experience in Europe has been mainly associated with the methyl esters of Rapeseed oil and in the US with Soybean derived fuels</u>. Whether or not the service experience with these fuels will apply/ extend to all fatty acid methyl esters (including such as Tallow ME and Used Frying Oil ME) has yet to be determined. FAMEs tested so far appear to have good lubricity and cetane numbers.

FIE Manufacturers Concerns:

FAMEs are derived from a wide range of base stocks, resulting in a similarly wide range of finished fuel characteristics.

Amongst the concerns of the FIE manufacturers are the following fuel characteristics:-

- Free methanol ***- Dissolved and free water*** ***- Free glycerin***

- Mono and di glycerides ***- Free fatty acids*** ***- Total solid impurity levels***

- Alkaline metal compounds in solution. ***Oxidation and thermal stability***

As currently manufactured, these fuels are less stable than mineral oil derived fuels. FAME fuels readily "bio-degrade" in the event of accidental spillage or leakage - this is claimed as a marketing advantage- The degradation propensity is, however, of major concern to the FIE manufacturers as the products of this natural process can be potentially harmful to the fuel system.

Our tests have shown that fuel degradation can take place in the fuel supply chain and in the vehicle fuel system; it is accelerated by the presence of oxygen, water, heat and impurities. The products of bio-degradation have been shown to be corrosive (e.g. formic, acetic and organic acids, water and methanol) and polymerisation products drop out within mixes with mineral fuels.

During extensive field trials conducted by the FIE Manufacturers in collaboration with end-users, the following injection equipment and engine problems have been identified as being caused by these fuel characteristics:-

- Corrosion of FIE components. ***- Elastomeric seal failures***
- Low pressure fuel system blockage ***- Fuel injector spray hole blockage***
- Increased dilution and polymerisation of engine sump oil
- Pump seizures due to high fuel viscosity at low temperatures
- Increased injection pressure

The incidence of these effects is likely to be increased when the engine is in irregular use, in applications such as stand-by generator units, automatic plant and seasonally used vehicles. (A list of potential problems is attached at the end of this document)

Fuel Quality Control Requirements:

Several initiatives are currently underway, to define Standards for fatty acid methyl ester fuels. For vegetable oil methyl esters (VOME), Austrian, Italian, German and French Standards already exist as well as a draft European Standard, but it is recognised that these do not fully specify the fuel requirements to a sufficient level to protect the end-user. In particular the fuel ageing propensity is poorly defined and few controls are implemented.

Within the European Community, CEN technical committee TC19 has been given the responsibility to evolve Standards of FAME for diesel engine use, viz.,

a) 100% FAME as a complete replacement for diesel fuel
b) FAME fuel as a blending component for use with mineral diesel fuel to comply with EuroNorme EN590 with up to 5%(vol) FAME.

International Standards Organisation committee TC28 will liaise with this group with regard to an eventual world-wide standard. ASTM in the U.S. is involved in similar work.

The latest proposed draft German specification from DIN for FAME (E-DIN51606) contains most of the items proposed by the FIE manufacturers for inclusion in an acceptable standard. Uppermost in these requirements are the following:-

- Oxidation Stability ***- Thermal Stability*** ***- Total Acid Number*** ***- Iodine Number***

- Water Content ***- Content of methanol, free glycerine & glycerides*** ***Flash Point***

- Low Temperature Operability parameters such as viscosity, CFPP & pour point.

It is anticipated that, to reach acceptable levels for these parameters the development and inclusion of suitable fuel additives and appropriate test methods will be required.

For determination of oxidation stability, it is being proposed to use a modified IP306 procedure. Current experience suggests that the best of the FAME fuels tested cannot better an "induction period" of four hours. Fuels without additives to improve this characteristic are of concern to the FIE manufacturers

Diesel Fuel Injection Equipment Manufacturers

Common Position Statement on Fatty Acid Methyl Ester (FAME) Fuels as a Replacement or Extender for Diesel Fuels

The FIE Manufacturers Position:

FIE manufacturers encourage the development of renewable compression ignition fuels. Experience to date with Rapeseed Methyl Ester fuels in Europe suggests that with fuels conforming to the existing national FAME standards at the point of sale in mixtures containing up to 5% volume RME, in mineral diesel fuel complying with currently accepted quality Standards, should not give end-users any serious problems.

Certain vehicle models have been adapted by their makers to use blends of 5% and above of good quality RME fuels in mineral diesel fuel. Other vehicles are adapted for using 100% good quality RME. The FIE manufacturers can supply equipment suitable for these applications.

The original quality of the FAME fuel is defined in draft National Standards which cover all relevant impurities and tramp chemicals from the processing. Suppliers of FAME fuels must be able to demonstrate compliance to these draft Standards at the point of delivery to the vehicle or plant.

International Standards are based on experience gained with the National Standards being developed to specify the original quality and long term stability of FAMEs. For the FIE manufacturers a key part of these Standards is resistance to oxidation. Aged or poor quality FAME contains organic acids, free water, peroxides and products of polymerisation which attack many components thereby drastically reducing the service life of the FIE. A full list of issues which have been witnessed in service is in the Attachment.

Even if these fuels comply with a suitable Standard as delivered, the enhanced care and attention required to maintain the fuels in vehicle or other tanks may entail a high risk of non-compliance to the Standard during use.

The FIE manufacturers can accept no legal liability for failure attributable to operating their products with fuels for which the products were not designed, and no warranties or representations are made as to the possible effects of running these products with such fuels.

Non-compliance of the fuel to Standards agreed by the FIE manufacturers, whether being evident by appearance of the known degradation products of these fuels, or their known effects within the fuel injection equipment, (see attached list of known issues) will render the FIE Manufacturers' guarantee null & void.

Attachment

Fuel injection equipment - potential problems with FAME

(non exhaustive list)

Fuel Characteristic	Effect	Failure Mode
Fatty acid methyl esters (general)	-Causes some elastomers including Nitrile rubbers to soften, swell, or harden and crack	Fuel Leakage
Free methanol in FAME	-Corrodes aluminium & zinc -Low flash point	Corrosion of FIE
FAME process chemicals	Potassium and sodium compounds Solid particles	Blocked Nozzles
Dissolved water in FAME	Reversion of FAME to fatty acid	Filter Plugging
Free water in mixtures	Corrosion Sustains bacteria Increases the electrical conductivity of fuel	Corrosion of FIE Sludging
Free glycerine	Corrodes non ferrous metals Soaks cellulose filters Sediments on moving parts and Lacquering	Filter clogging Injector Coking
Mono- & di-glyceride	Similar to glycerine	
Free fatty acid	Provides an electrolyte and hastens the corrosion of zinc Salts of organic acids Organic compounds formed	Corrosion of FIE Filter plugging Sediments on parts
Higher modulus of elasticity	Increases injection pressure	Potential of reduced service life
High viscosity at low temperature	Generates excessive heat locally in rotary distributor pumps Higher stressed components	Pump seizures Early life failures Poor nozzle spray atomisation
Solid impurities	Potential lubricity problems	Reduced service life
Ageing products		
Corrosive acids (formic & acetic)	Corrodes all metallic parts may form simple cell	Corrosion of FIE
Higher molecular organic acids	Similar to fatty acid	
Polymerisation products	Deposits especially from fuel mixes	Filter plugging Lacquering formation in hot areas

The views contained in this Common Position Statement are those of the FIE Manufacturers, which comprise the following:-

Signed on behalf of
Delphi Diesel Systems

....
Dr M Norman
Technical Director
Delphi Diesel Systems

Signed on behalf of
Stanadyne Automotive Corp.

....
Mr William Kelly
Vice President & General Manager
Fuel Injection Pumps
Diesel Systems Group

Signed on behalf of
DENSO CORPORATION

....
Mr Masami Manabe
Director
Diesel Injection Product Division

Signed on behalf of
Robert Bosch GmbH

....
Mr K Krieger
Senior Vice President Engineering
Automotive Equipment Group Systems
Diesel FIE Division.K5

Appendix G: Engine Manufacturers Association Technical Statement on the Use of Biodiesel Fuel in Compression Ignition Engines

Engine Manufacturers Association
www.enginemanufacturers.org
Two North LaSalle Street
Suite 2200
Chicago, Illinois 60602
Tel: 312/827-8700
Fax: 312/827-8737

TECHNICAL STATEMENT ON THE USE OF BIODIESEL FUEL IN COMPRESSION IGNITION ENGINES

Introduction

The Engine Manufacturers Association ("EMA") is an international membership organization representing the interests of manufacturers of internal combustion engines.

In 1995, EMA published a "Statement on the Use of Biodiesel Fuels for Mobile Applications." Since that time, increased worldwide interest in reducing reliance on petroleum-based fuels and improving air quality has led many stakeholders, including engine manufacturers, to continue to investigate the use of alternative, renewable fuels, including biodiesel fuels, as a substitute for conventional diesel fuel. In addition, recent government proposals in the United States and Europe have called for incentives or mandates to increase the production and use of such renewable fuels.

This Statement, which takes into consideration additional laboratory and field research conducted since the publication of the 1995 Statement, sets forth EMA's position on the use of biodiesel fuels with current engine technologies. It should be noted, however, that only limited data is available regarding the use of biodiesel with those technologies that have been, or are about to be, introduced to meet the (US) Environmental Protection Agency's ("EPA's") 2004 heavy-duty on-highway emission standards. Moreover, because of the absence of available data, the Statement does not address the potential use of biodiesel fuels with advanced emission control technologies, including aftertreatment systems designed for future ultra-low emission engines.

Biodiesel

Biodiesel fuels are methyl or ethyl esters derived from a broad variety of renewable sources such as vegetable oil, animal fat and cooking oil. Esters are oxygenated organic compounds that can be used in compression ignition engines because some of their key properties are comparable to those of diesel fuel.

"Soy Methyl Ester" diesel ("SME" or "SOME"), derived from soybean oil, is the most common biodiesel in the United States. "Rape Methyl Ester" diesel ("RME"), derived from rapeseed oil, is the most common biodiesel fuel available in Europe. Collectively, these fuels are sometimes referred to as "Fatty Acid Methyl Esters" ("FAME").

Biodiesel fuels are produced by a process called transesterification, in which various oils (triglycerides) are converted into methyl esters through a chemical reaction with methanol in the presence of a catalyst, such as sodium or potassium hydroxide. The by-products of this chemical reaction are glycerols and water, both of which are undesirable and need to be removed from the fuel along with traces of the methanol, unreacted triglycerides and catalyst. Biodiesel fuels naturally contain oxygen, which must be stabilized to avoid storage problems. Although biodiesel feedstock does not inherently contain sulfur, sulfur may be present in biodiesel fuel because of contamination during the transesterification process and in storage.

Biodiesel Specifications

Biodiesel is produced in a pure form (100% biodiesel fuel referred to as "B100" or "neat biodiesel") and may be blended with petroleum-based diesel fuel. Such biodiesel blends are designated as BXX, where XX represents the percentage of pure biodiesel contained in the blend (e.g., "B5," "B20").

Several standard-setting organizations worldwide have recently adopted biodiesel specifications. Specifically, ASTM International recently approved a specification for biodiesel referenced as D 6751. In addition, German authorities have issued a provisional specification for FAME under DIN 51606. And, Europe's Committee for Standardization ("CEN") is in the final stages of setting a technical standard for biofuels to be referred to as EN 14214. The European specifications include more stringent limits for sulfur and water, as well as a test for oxidation stability, which is absent from the current ASTM specification.

Depending on the biomass feedstock and the process used to produce the fuel, B100 fuels should meet the requirements of either ASTM D 6751 or an approved European specification, such as DIN 51606 or EN 14214 (once adopted).

In addition, it should be noted that the National Biodiesel Board has created the National Biodiesel Accreditation Commission to develop and implement a voluntary program for the accreditation of producers and marketers of biodiesel. The Commission has developed a standard entitled, "BQ-9000, Quality Management System Requirements for the Biodiesel Industry," for use in the accreditation process.

Biodiesel Blends

Public and private bodies recently have taken positions regarding the use of biodiesel blends. For example, the (United States) Energy Policy Act of 1992 ("EPAct") was amended in 1998 to allow covered fleets to use biodiesel to fulfill up to fifty percent (50%) of their annual alternative fuel vehicle (AFV) acquisition requirements. Under EPAct's Biodiesel Fuel Use Credits provisions, covered fleets are allocated one biodiesel fuel use credit (the equivalent of a full vehicle credit) for each 450 gallons of B100 purchased and consumed. Such credits are awarded only if the blended fuel contains at least twenty percent biodiesel (B20) and is used in new or existing vehicles weighing at least 8500 pounds. No credits are awarded for biodiesel used in a vehicle already counted as an AFV.

During the same time period, however, a consortium of diesel fuel injection equipment manufacturers ("FIE Manufacturers") issued a position statement concluding that blends greater than B5 can cause reduced product service life and injection equipment failures.[1] According to the FIE Manufacturers' Position Statement, even if the B100 used in a blend meets one or more specifications, "the enhanced care and attention required to maintain the fuels in vehicle tanks may make for a high risk of non-compliance to the standard during use." As a result, the FIE Manufacturers disclaim responsibility for any failures attributable to operating their products with fuels for which the products were not designed.

Based on current understanding of biodiesel fuels and blending with petroleum-based diesel fuel, EMA members expect that blends up to a maximum of B5 should not cause engine or fuel system problems, provided the B100 used in the blend meets the requirements of ASTM D 6751, DIN 51606, or EN 14214. If blends exceeding B5 are desired, vehicle owners and operators should consult their engine manufacturer regarding the implications of using such fuel.

Engine Operation, Performance and Durability

The energy content of neat biodiesel fuel is about eleven percent (11%) lower than that of petroleum-based diesel fuel (on a per gallon basis), which results in a power loss in engine operation. The viscosity range of biodiesel fuel, however, is higher than that of petroleum-based diesel fuel (1.9 – 6.0 centistokes versus 1.3 – 5.8 centistokes), which tends to reduce barrel/plunger leakage and thereby slightly improve injector efficiency. The net effect of using B100, then, is a loss of approximately five to seven percent (5-7%) in maximum power output. The actual percentage power loss will vary depending on the percentage of biodiesel blended in the fuel. Any adjustment to the engine in service to compensate for such power loss may result in a violation of EPA's anti-tampering provisions. To avoid such illegal tampering, as well as potential engine problems that may occur if the engine is later operated with petroleum-based diesel fuel, EMA recommends that users not make such adjustments.

Neat biodiesel and higher percentage biodiesel blends can cause a variety of engine performance problems, including filter plugging, injector coking, piston ring sticking and breaking, elastomer seal swelling and hardening/cracking, and severe engine lubricant degradation. At low ambient temperatures, biodiesel is thicker than conventional diesel fuel, which would limit its use in certain geographic areas. In addition, elastomer compatibility with biodiesel remains unclear; therefore, when biodiesel fuels are used, the condition of seals, hoses, gaskets, and wire coatings should be monitored regularly.

There is limited information on the effect of neat biodiesel and biodiesel blends on engine durability during various environmental conditions. More information is needed to assess the viability of using these fuels over the mileage and operating periods typical of heavy-duty engines.

[1] See, "Diesel Fuel Injection Equipment Manufacturers Common Position Statement on Fatty Acid Methyl Ester Fuels as a Replacement or Extender for Diesel Fuels" (May 1, 1998).

Emission Characteristics

In October 2002, U.S. EPA released a draft report entitled, "A Comprehensive Analysis of Biodiesel Impacts on Exhaust Emissions." The draft technical report can be found on the EPA Web site at: http://www.epa.gov/otaq/models/biodsl.htm.

Use of neat biodiesel and biodiesel blends in place of petroleum-based diesel fuel may reduce visible smoke and particulate emissions, which are of special concern in older diesel engines in non-attainment areas. In addition, B100 and biodiesel blends can achieve some reduction in reactive hydrocarbons ("HC") and carbon monoxide ("CO") emissions when used in an unmodified diesel engine. Those reductions are attributed to the presence of oxygen in the fuel. Oxygen and other biodiesel characteristics, however, also increase oxides of nitrogen ("NOx") in an unmodified engine. As a result, B100 and biodiesel blends produce higher NOx emissions than petroleum-based diesel fuel. As such, EMA does not recommend the use of either B100 or biodiesel blends as a means to improve air quality in ozone non-attainment areas.

Storage and Handling

Biodiesel fuels have shown poor oxidation stability, which can result in long-term storage problems. When biodiesel fuels are used at low ambient temperatures, filters may plug, and the fuel in the tank may thicken to the point where it will not flow sufficiently for proper engine operation. Therefore, it may be prudent to store biodiesel fuel in a heated building or storage tank, as well as heat the fuel systems' fuel lines, filters, and tanks. Additives also may be needed to improve storage conditions and allow for the use of biodiesel fuel in a wider range of ambient temperatures. To demonstrate their stability under normal storage and use conditions, biodiesel fuels, tested using ASTM D 6468, should have a minimum of 80% reflectance after aging for 180 minutes at a temperature of 150°C. The test is intended to predict the resistance of fuel to degradation at normal engine operating temperatures and provide an indication of overall fuel stability.

Biodiesel fuel is an excellent medium for microbial growth. Inasmuch as water accelerates microbial growth and is naturally more prevalent in biodiesel fuels than in petroleum-based diesel fuels, care must be taken to remove water from fuel tanks. The effectiveness of using conventional anti-microbial additives in biodiesel is unknown. The presence of microbes may cause operational problems, fuel system corrosion, premature filter plugging, and sediment build-up in fuel systems.

Health & Safety

Pure biodiesel fuels have been tested and found to be nontoxic in animal studies. Emissions from engines using biodiesel fuel have undergone health effects testing in accordance with EPA Tier II requirements for fuel and fuel additive registration. Tier II test results indicate no biologically significant short term effects on the animals studied other than minor effects on lung tissue at high exposure levels.

Biodiesel fuels are biodegradable, which may promote their use in applications where biodegradability is desired (e.g., marine or farm applications).

Biodiesel is as safe in handling and storage as petroleum-based diesel fuel.

Warranties

Engine manufacturers are legally required to provide an emissions warranty on their products (which are certified to EPA's diesel fuel specification) and, typically, also provide commercial warranties. Individual engine manufacturers determine what implications, if any, the use of biodiesel fuel has on the manufacturers' commercial warranties. It is unclear what implications the use of biodiesel fuel has on emissions warranty, in-use liability, anti-tampering provisions, and the like. As noted above, however, more information is needed on the impacts of long-term use of biodiesel on engine operations.

Economics

The cost of biodiesel fuels varies depending on the basestock, geographic area, variability in crop production from season to season, and other factors. Although the cost may be reduced if relatively inexpensive feedstock, such as waste oils or rendered animal fat, is used instead of soybean, corn or other plant oil, the average cost of biodiesel fuel nevertheless exceeds that of petroleum-based diesel fuel.

That said, users considering conversion to an alternative fuel should recognize that the relative cost of converting an existing fleet to biodiesel blends is much lower than the cost of converting to any other alternative fuel because no major engine, vehicle, or dispensing system changes are required.

Conclusions

- Depending on the biomass feedstock and the process used to produce the fuel, B100 fuels should meet the requirements of either ASTM D 6751 or an approved European specification.

- Biodiesel blends up to a maximum of B5 should not cause engine or fuel system problems, provided the B100 used in the blend meets the requirements of ASTM D 6751, DIN 51606, or EN 14214. Engine manufacturers should be consulted if higher percentage blends are desired.

- Biodiesel blends may require additives to improve storage stability and allow use in a wide range of temperatures. In addition, the conditions of seals, hoses, gaskets, and wire coatings should be monitored regularly when biodiesel fuels are used.

- Although the actual loss will vary depending on the percentage of biodiesel blended in the fuel, the net effect of using B100 fuel is a loss of approximately 5-7% in maximum power output.

- Neat biodiesel and biodiesel blends reduce particulate, HC and CO emissions and increase NOx emissions compared with petroleum-based diesel fuel used in an unmodified diesel engine. Neither B100 nor biodiesel blends should be used as a means to improve air quality in ozone non-attainment areas.

- Biodiesel fuels have generally been found to be nontoxic and are biodegradable, which may promote their use in applications where biodegradability is desired.

- Individual engine manufacturers determine what implications, if any, the use of biodiesel fuel has on the manufacturers' commercial warranties.

- Although several factors affect the cost of biodiesel fuel, its average cost exceeds that of petroleum-based diesel fuel. The relative cost of converting an existing fleet to biodiesel blends, however, is much lower than the cost of converting to other alternative fuel.

DATED: February 2003

Appendix H: List of the Diesel Engine Manufacturers' Specific Positions and Maintenance Concerns Regarding Using Biodiesel Blends

Engine Manufacturers' Positions on Using Biodiesel/Biodiesel Blends

Caterpillar – (March 2001) Using biodiesel is neither approved of, nor prohibited. Using biodiesel does not affect the Materials and Workmanship warranty. Failures resulting from the use of any fuel are not Caterpillar factory defects and therefore the cost of repair would *not* be covered by Caterpillar's warranty (16).

Caterpillar models where biodiesel blends following ASTM PS121 or DIN 51606 (<=B20): 3046, 3064, 3066, 3114, 3116, 3126, 3176, 3196, 3208, 3306, C-10, C-12, 3406, C-15, C-16, 3456, 3408, 3412, 3500 Series, 3600 Series, CM20, CM25, and CM32.

Caterpillar models where biodiesel blends following ASTM PS121 or DIN 51606 (<=B5): 3303 through 3034, 3054, and 3056.

Cummins – (August 2001) biodiesel is considered experimental. Using biodiesel is neither approved of, nor prohibited. Using biodiesel does not affect the Materials and Workmanship warranty (17). Failures caused by the use of biodiesel fuels or other fuel additives are not defects of workmanship and/or material supplied by Cummins, Inc. and cannot be compensated under Cummins' warranty. It would be expected that blending up to 5% volume concentration should not cause serious problems. Bosch states in their Diesel Fuel Quality – Common Position Paper (03/05/99) that no guarantee on FIE is given so far as any alternative fuel except Diesel +5% FAME. There is a major difference between operating on pure (100% concentration) Biodiesel fuels and biodiesel/petroleum diesel blends.

Detroit Diesel – Biodiesel blends up to 20% that meet the company requirements can be used, *but* failures attributed to the use of biodiesel will not be covered by Detroit Diesel product warranty (18).

International – International recognizes the biodiesel specification, but neither approves nor disapproves any product not manufactured by International (19). The use of biodiesel is at the discretion of the end user. Any engine performance problem or failure attributed to biodiesel would not be recognized as the responsibility of International Engine Corporation. International's warranty covers defects caused by materials or workmanship. The International engine warranty, workmanship and materials is not affected simply by the use of biodiesel regardless of the product's origin. Fuel is not warranted by International under any condition.

John Deere -

John Deere models where biodiesel blends following ASTM PS121 or DIN 51606 (<=B5): 6200, 6300, 6400, 6405, 6605, 6110, 6210, 6310, 6410, 6120, 6220, 6320, 6420, 7200, 7210, 7220, 7320, 7400, 7410, 7405, 7420, 7510, 7520, 7600, 7610, 7700, 7710, 7800, 7810, 8100, 8200, 8300, 8400, 8110, 8210, 8310, 8410, 8120, 8220, 8320, 8420, 8520, 8110T, 8201T, 8310T, 8410T, 8120T, 8220T, 8320T, 8420T, 8520T, 9100, 9200, 9300, 9400, 9120, 9220, 9320, 9420, 9520, 9300T, 9400T, 9320T, 9420T, 9520T (20)

Engine Manufacturer Service Issues and Recommendations for Biodiesel/Biodiesel Blends

Caterpillar

- Oil change intervals can be affected and Scheduled Oil Sampling (SOS) should be used to determine oil change intervals
- Engine should not be tuned to compensate for 5-7% lower power on biodiesel because of problems if the engine is returned to pure diesel fuel.
- Elastomer compatibility still being monitored. Seals and hoses should be checked regularly.
- Low ambient temperatures – fuel/fuel lines may need to be heated. Fuel lines/filters can be plugged
- Poor oxidation stability – long-term storage problems. May accelerate fuel oxidation; esp. important in engines with electronic fuel systems because of higher operating temperatures.
- Microbial growth – biodegradable, so easily grows microbes, which can plug filters and corrode fuel system. Not known whether conventional anti-microbial additives work.
- Water in tank – accelerates microbe growth. Water is much more naturally prevalent in Biodiesel than diesel fuel.

Cummins

- Engine should not be tuned to compensate for 5-7% lower power in biodiesel because of problems if the engine is returned to pure diesel fuel.
- Elastomer compatibility still being monitored. Seals and hoses should be checked regularly.
- Low temperature operation – fuel gelling, filter plugging
- Heat content – lower fuel economy
- Storage and thermal stability (filter plugging, injector deposits)
- Oil change interval can be affected; can require oil change intervals half as long.
- Swelling/cracking of elastomer seals in fuel system/engine
- Corrosion of fuel system and engine hardware – especially Zn, Al
- Solid particle blockage of fuel nozzles and passages
- Filter plugging
- Injector coking
- Higher injection pressures (due to higher bulk modulus of fuel) – shorter fuel system life
- Added stress to injection components – esp. rotary pumps, increased pump seizures and early life failures.
- Poor spray atomization – reduced fuel economy
- B100 is not stable and increases in acid content (water bonds to fuel forming acid)
- Poor oxidation stability – long-term storage problems. May accelerate fuel oxidation; esp. important in engines with electronic fuel systems because of higher operating temperatures.
- Microbial growth – biodegradable, so easily grows microbes, which can plug filters and corrode fuel system. Not known whether conventional anti-microbial additives work.
- Water in tank – accelerates microbe growth. Water is much more naturally prevalent in Biodiesel than diesel fuel.