# A Demonstration of HEFA SPK/JP-8 Fuel Blend at the Camp Grayling Joint Maneuver Training Center

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# EXECUTIVE SUMMARY


## Purpose

The purpose of the demonstration was to capture "real-world" vehicle data and perceptions of military personnel while a variety of tactical ground vehicles and equipment were operated on a candidate "drop-in" alternative fuel for the Single Battlefield Fuel, JP-8. The candidate drop-in fuel is a blend of up to 50% by volume of Hydroprocessed Esters and Fatty Acids Synthetic Paraffinic Kerosene (HEFA SPK) and JP-8. The results from this demonstration will augment a significant set of evaluations already completed that indicate this biofuel is a viable drop-in fuel to replace petroleum-based JP-8.

## Importance of Demonstration

This demonstration was completed as part of the Tank Automotive Research, Development, and Engineering Center (TARDEC) program to qualify alternative fuels for military use. The qualification of non-petroleum derived fuels supports Army and Department of Defense (DoD) strategic energy goals for increased use of alternative energy. Although extensive laboratory evaluations based on fuel analysis, component rig and engine dynamometer testing, or evaluations on a test track outside a physical laboratory may be conducted to establish the viability of a candidate fuel as a drop-in for JP-8, there is no substitute for getting fuel into the "hands of the user" to capture "real world" data and Soldier feedback from vehicles and equipment operating on the fuel.

## Approach

A total of 10,000 gallons of the biofuel blend was provided for the purpose of conducting a demonstration on a non-interference basis to the mission of the Joint Maneuver Training Center at Camp Grayling, Michigan. Selected Army Michigan National Guard (MING) units operated a variety of tactical ground vehicles and other equipment they brought with them to Camp Grayling on the biofuel as they performed their annual training exercises during the summer of 2012.

## Accomplishments

The Army MING units involved in this demonstration consumed a total of 10,000 gallons of the biofuel blend in a variety of equipment that included several types of tactical ground vehicles, in addition to other equipment. The tactical ground vehicles that operated with the biofuel included HMMWVs, uparmored HMMWVs, M915 line haul trucks, HEMTTs, FMTVs, LMTV vans, MTVs, and ambulances. Other equipment that operated on the alternative fuel included generators, light sets, construction equipment, environmental control units, and containerized kitchen trailer and laundry units. Throughout the duration of this demonstration, no significant or unexpected issues arose with vehicles or other equipment that operated on the biofuel. Soldiers' perceptions of how their equipment performed on the biofuel did indicate they noticed some differences in comparison to the diesel fuel they normally use. These differences were expected since the biofuel blend is a drop-in replacement for JP-8 (jet) fuel rather than diesel fuel.

## Military Impact

The U.S. Military will be prepared to utilize the non-petroleum derived fuels that are making their way into the global fuels supply. This preparation is accomplished by approving the use of emerging alternative fuels that are determined, through qualification and certification (aircraft), to be "drop-in" replacements for the Single Battlefield Fuel (JP-8/JP-5/Jet A-1).

## FOREWARD/ACKNOWLEDGMENTS

This demonstration is part of a Tank Automotive Research, Development, and Engineering Center (TARDEC) program to qualify alternative fuels for use by the Army and Department of Defense (DoD) in military ground vehicles (tactical/combat) and equipment. This demonstration was conducted at Camp Grayling, Michigan as a joint effort by TARDEC and the Army National Guard (ARNG) / Michigan National Guard (MING). TARDEC participation was spearheaded by the National Automotive Center (NAC) in coordination with the Fuels and Lubricants Technology Team (FLTT). In addition, the Navy provided a portion of the alternative fuel utilized in this demonstration because the ground vehicle and equipment technologies involved are similar to those found in Navy (Marine Corps) fleets.

The following individuals are recognized for their contributions in the support and execution of a successful demonstration:

**U.S. Army Michigan National Guard**

Brigadier General Michael A. Stone, Adjutant General
Colonel (r) Keith Bobenmoyer, Senior Liaison Officer, Office of the Assistant Adjutant General-Installations
Lieutenant Colonel Steve Ward, Michigan National Guard Facilities Management Officer
Lieutenant Colonel Bruce Revers, Deputy Chief of Staff for Logistics
Major Andy Kuhns, Michigan Environmental Manager
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**U.S. Navy**

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Ms. Lynda Turner, NAVSUP Energy, Alternative Fuels Logistics/Energy Futures

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# I. PURPOSE

The purpose of the demonstration was to capture "real-world" vehicle data and perceptions of military personnel while a variety of tactical ground vehicles and equipment were operated on a candidate "drop-in" alternative fuel for the Single Battlefield Fuel, JP-8. The candidate drop-in fuel is a blend of up to 50% by volume of Hydroprocessed Esters and Fatty Acids Synthetic Paraffinic Kerosene (HEFA SPK) and JP-8. The results from this demonstration will augment a significant number of other evaluations already completed to establish this biofuel as a viable drop-in fuel to replace petroleum-based JP-8. A list of reports on TARDEC evaluations completed through September 2012 on HEFA SPK, and also very similar SPK produced via the Fischer-Tropsch (FT) process, are provided in Appendix A. Additional reports will become available in the future for the TARDEC evaluations still in progress. Also, there are numerous, publically available reports on evaluations of HEFA SPK and FT SPK fuel blends completed by the Air Force, Navy, and commercial aviation stakeholders.

# II. BACKGROUND

The DoD Operational Energy Strategy, issued for the first time in a May 2011 report, makes it clear that DoD needs to diversify its energy sources as part of better assuring a supply of energy for military missions.[1] The Army Energy Security Implementation Strategy, issued in January 2009, identifies the increased use of alternative energy as one of five Army energy security goals.[2] Army, Air Force, and Navy efforts to qualify and approve alternative jet fuels to replace petroleum-based "Single Battlefield Fuel", specifically JP-8, JP-5, and/or additized Jet A-1, for use by the military directly support these operational energy strategies. In addition, these efforts can contribute to national goals such as reducing dependence on petroleum, lowering emissions of greenhouse gases, and stimulating innovation in the civilian sector.

The Air Force alternative fuels goal is to be prepared to acquire half of its domestic aviation fuel requirement via a cost competitive alternative fuel blend by 2016.[3] The Navy demonstrated a "Great Green Fleet" via a Carrier Strike Group that operated on HEFA-based blends of JP-5 (Navy "JP-8") and F-76 (marine diesel fuel) during the Rim of the Pacific (RIMPAC) exercise in the summer of 2012. The Navy goals are to sail a Great Green Fleet on these alternative fuel blends by 2016 and to use alternative sources for half of all energy consumption afloat by 2020. [4] The Army will demonstrate a Green Warrior Convoy in the spring of 2013 that will include a mix of tactical vehicles operating on an alternative fuel replacement for JP-8.[5]

Alternative fuels for use in military weapons platforms and vehicles must be "drop-in" replacements for currently used fuels.[1] A drop-in replacement fuel is said to be "transparent to the user" in that it:

- Meets fuel performance requirements
- Requires no change to aircraft or ship
- Requires no change to infrastructure
- Can be mixed or alternated with petroleum fuel

TARDEC is conducting the program to qualify and approve drop-in replacements for JP-8 for use in Army/DoD tactical and combat ground vehicles and tactical ground equipment. The first two candidate drop-in alternative fuels are progressing through qualification concurrently; both fuels are blends of up to 50% by volume of Synthetic Paraffinic Kerosene (SPK) and JP-8. One SPK is manufactured via a Fischer-Tropsch (FT) process, and the other is manufactured from Hydroprocessed Esters and Fatty Acids (HEFA). The concurrent qualification of these two fuel blends is possible because of their compositional similarity to one another.

Qualification and approval of a new fuel is addressed through a standardized process that is common amongst the Tri-Services (Army, Air Force, and Navy). A series of evaluations are completed to assess the capability of the candidate alternative fuel as a drop-in replacement for the currently used fuel. Standardized and/or controlled testing is conducted and the data generated is analyzed to determine what, if any, additional testing is required. The initial testing generates data about the candidate fuel itself, such as its chemical composition and physicochemical properties, its compatibility with materials in military equipment, and its environmental and health impacts. Additional testing is typically completed to evaluate the performance and/or durability impacts the candidate fuel may have on subsystems, such as fuel pumps or engines, or on systems, such as generators or vehicles, when they are operated on the fuel.

If, as these above evaluations are nearing completion, they indicate that the candidate fuel is very likely a drop-in capable replacement fuel, it is time to consider a less controlled evaluation or demonstration. It is just such the case that brought TARDEC to the point to initiate this demonstration of the HEFA SPK/JP-8 fuel blend with the support of the Army MING at Camp Grayling.

# III. APPROACH

A total of 10,000 gallons of HEFA SPK/JP-8 fuel blend was delivered to Camp Grayling for the purpose of this demonstration. Selected Army MING units conducted this demonstration of the fuel over a two week period, on a non-interference basis, during the course of their annual summer training exercise. Army MING units operated a variety of tactical ground vehicles and other tactical equipment they brought with them from their home installations using the alternative fuel blend. Participating units generated data about the use of this fuel based on what they normally record regarding their training activities. In addition, TARDEC created a photo record of the demonstration, as well as a written record to capture Soldier feedback about the operation and performance of their equipment while operating on the fuel.

# IV. RESULTS

## HEFA SPK/JP-8 Blend Demonstrated

The 10,000 gallons of HEFA SPK/JP-8 fuel blend was delivered to Camp Grayling in two tanker truck loads of approximately 5,000 gallons each. The properties of the delivered fuel blend are shown in Tables B-1 and B-2, Appendix B, for the 1$^{st}$ and 2$^{nd}$ tanker truck deliveries, respectively. The first tanker truck delivered the fuel to the Camp Grayling Joint Maneuver Training Center on 14 June 2012, while the second tanker truck arrived on 25 June 2012. Both deliveries of fuel represent a fuel blend created by blending in as close to the maximum volume of HEFA SPK allowed per the JP-8 specification, specifically 50% by volume, while allowing for some slight deviation from the specification on two other properties – aromatic content and density. In actual practice, the volume of HEFA SPK blended in might be less than the 50% maximum limit in order for the blend to meet all of the specification requirements, particularly for minimum density of 0.775 kg/L, minimum aromatic content of 8.0% vol, and minimum Derived Cetane Number (DCN) of 40.

## Environment

Records of TARDEC assigned personnel that traveled to Camp Grayling in support of the demonstration indicated that:

> "The Camp Grayling location is in the mid part of lower Michigan, the area is very sandy with surrounding trees and hills. The Forward Operating Base (FOB) area was mostly flat and sandy. The training lanes started out in a hilly wooded area with sand roads and ended in a flat open sandy area."

> "Weather during the training and evaluation was typical for spring and summer in Michigan. Highs for the day went from 72°F to almost 100°F and lows went from 41°F to 68°F, there was a bit of rain but there were no severe storms."

## Participating Army MING Units and Equipment

The HHC 272nd, 1225th, 146 MMB, 1171 ASMC, and 238th, units of the 272nd Regional Support Group, participated in the demonstration. Each unit conducted their entire training event, 17-29 June 2012, with equipment they brought with them from their home bases and using the HEFA SPK/JP-8 fuel blend. A total of 223 military equipment items were powered by the HEFA SPK/JP-8 fuel blend. Figure 1 shows the breakout of this equipment according to its Army Program Manager (PM) affiliation. The equipment was affiliated with PEO CS&CSS, PEO C3T, and PEO Aviation, with the majority of equipment affiliated with PEO CS&CSS.

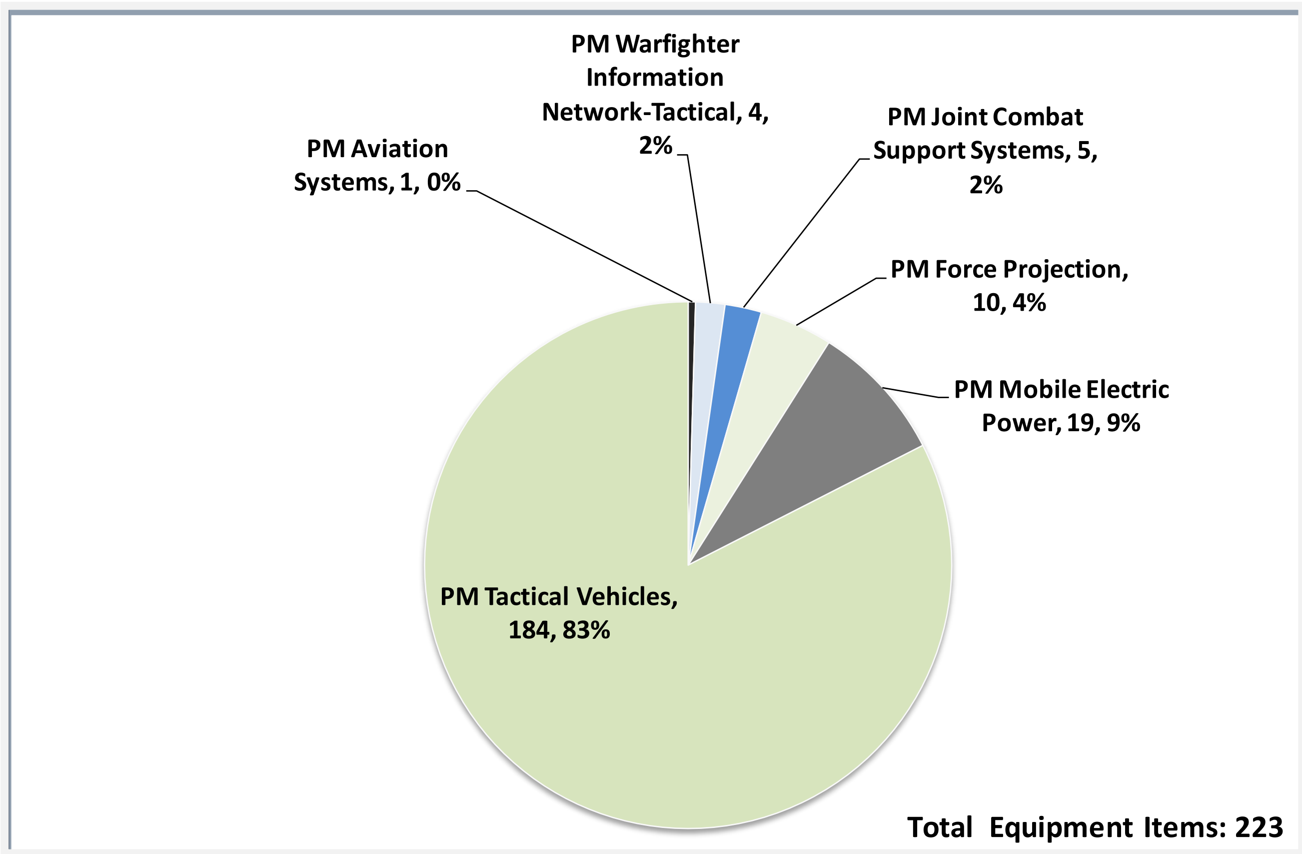


**Figure 1 • Equipment Density by PM Affiliation**

Shown in Table 1 is a breakdown of equipment types that were powered by the HEFA SPK/JP-8 fuel blend. In addition, Table C-1 in Appendix C provides a more detailed breakdown of the equipment.

**Table 1 • Breakdown of Equipment Types**

| Equipment Item Description | Qty |
|---|---|
| PM Aviation Systems: | |
| MT3 Standard Aircraft Towing System | 1 |
| PM Warfighter Information Network-Tactical: | |
| Very Small Aperture Terminal (VSAT) | 2 |
| Trailer Mounted Support System (TMSS) | 2 |
| PM Joint Combat Support Systems: | |
| Forward Repair System (FRS) | 2 |
| Standard Automotive Tool Set (SATS) | 3 |
| PM Force Projection: | |
| Crane 7.5T | 1 |
| Forklift 10K | 3 |
| Containerized Kitchen (CK) | 1 |
| Laundry Advanced System (LADS) | 4 |
| Tank and Pumping Unit (TPU) | 1 |
| PM Mobile Electric Power: | |
| Generator | 14 |
| Environmental Control Unit (with generator) | 5 |
| PM Tactical Vehicles: | |
| High Mobility Multipurpose Wheeled Vehicle (HMMWV)* | 94 |
| M939 Truck Series | 7 |
| Family of Medium Tactical Vehicles (FMTV) | 43 |
| Medium Tactical Vehicle (MTV) | 11 |
| Light Medium Tactical Vehicle (LMTV) | 8 |
| Heavy Expanded Mobility Tactical Truck (HEMTT) | 11 |
| Line Haul Truck | 7 |
| Palletized Load System (PLS) | 3 |

*Includes 27 up-armored HMMWVs

## Soldier Feedback on Equipment Performance

The Soldiers provided feedback on the performance of their equipment near or at the end of their training event. This feedback was collected by TARDEC assigned personnel that engaged with Soldiers directly to hear from them what they observed and perceived regarding equipment performance when using the HEFA SPK/JP-8 fuel blend. The MING units routinely use diesel fuel rather than jet fuel (JP-8), so some of the feedback focused on performance differences between the use of diesel fuel and jet fuel. As a result of analyzing the feedback, it was determined that it could be separated into three categories: positive or negative performance feedback, and feedback on diesel-to-jet fuel comparisons. This report focuses on the positive and negative performance feedback only as the diesel-to-jet fuel comparison feedback is outside of the scope of this demonstration; further explanation is provided below. Table 2 provides a summary of the Soldier feedback based on observable equipment performance while operated on the HEFA SPK/JP-8 fuel blend.

**Table 2 • Feedback from Soldiers**

| Positive | Negative | |
|---|---|---|
| **No big issues, no major problems with vehicles** | **A few fuel pump issues** | |
| • Surprised by not being surprised – you'd think we would see more maintenance | Small-size generators (≤ 3-kW) | • Injection pumps "running hot" and shutting down; small-scale mechanical pumps are dropping like flies |
| • If something was going to go, it should have been there and was not [remark after running ambulances, HMMWVs-8, non-stop during one day of training] | HMMWV | • Replaced fuel pump twice on one HMMWV (not up-armored) |
| • Up-armored HMMWVs (12) got most use on 4-mile track with plenty of stop-start<br>• Medical vehicles had no issues, heated and cooled as needed, worked just fine | | |
| **Comparisons of Performance (Diesel-to-Jet Fuel)** | | |
| • Some fuel filters had to be replaced (switching from diesel to jet fuel)<br>• Higher fuel consumption; fuel seems to "burn quicker"<br>• Less horsepower<br>• Slower acceleration<br>• Fuel seems to "burn hotter" | | |

# V. DISCUSSION

## Equipment Performance – Positive Feedback

The positive feedback received on observed equipment performance focused on ground vehicles and this would be expected for a couple of reasons. First, of the total 223 equipment items that were powered with the HEFA SPK/JP-8 fuel blend, 83% of them were tactical ground vehicles. Second, ground vehicles put the fuel "to test" as a propulsive power energy source, rather than only as an energy source for stationary or auxiliary power generation. There was only one reported issue with one HMMWV (not up-armored) – its fuel pump had to be replaced twice. There is no way to know if the root cause of this fuel pump issue could be partly or entirely attributed to the fuel. However, it is reasonable to think that since there were no other reported fuel pump issues on the other 93 HMMWVs involved in the demonstration, that it is very unlikely that the fuel was the root cause of this one fuel pump issue.

Although HMMWVs (94) were by far the majority share of wheeled vehicles involved in the demonstration, there was also other on-/off-road equipment including Standard Aircraft Towing

System (1), Crane-7.5T (1), and Forklift-10K (3). There were no reported issues with the performance of this other equipment. The fact that only one of the 99 total items of on-/off-road equipment, or 1%, had any reported performance issue at all during this demonstration is a positive indicator as to the "drop-in" capability of the HEFA SPK/JP-8 fuel blend.

## Equipment Performance – Negative Feedback

All of the negative feedback on equipment performance during the demonstration had to do with fuel pumps. In one case only was poor fuel pump performance related to on-/off-road equipment, namely one HMMWV, as previously discussed. The remainder of reported poor fuel pump performance related to small-scale generators, specifically mechanical fuel injection pumps in 3-kW or smaller sized generators. The observation was that "small-scale mechanical pumps" were shutting down because of overheating.

The Line Item Numbers (LINs) or National Stock Numbers (NSNs) for this affected equipment were not provided, and therefore identification of the specific fuel injection systems involved is not possible. What was identified was that there were a total of 14 generators involved in the demonstration, although what they were specifically powering is not identified. Several other equipment items were identified that would typically be powered by a generator. However, all of these except possibly the Very Small Aperture Terminal (VSAT) are powered by generators larger than 3-kW size. Counting the specific generators identified, and also the equipment items typically powered by generators, there is a total of 33 items. The types and numbers of these items, denoted as "stationary equipment items" for the purposes of this report, are shown in Figure 2.

Assuming that the only small-scale mechanical pumps that were affected were in the 3-kW generators identified as equipment items, then only 3% of the total equipment items (18% of the total stationary equipment items) had observed negative performance during the demonstration. Figure 3 shows a breakdown of the equipment items with observed negative performance as a percentage of the total equipment items and total stationary equipment items.

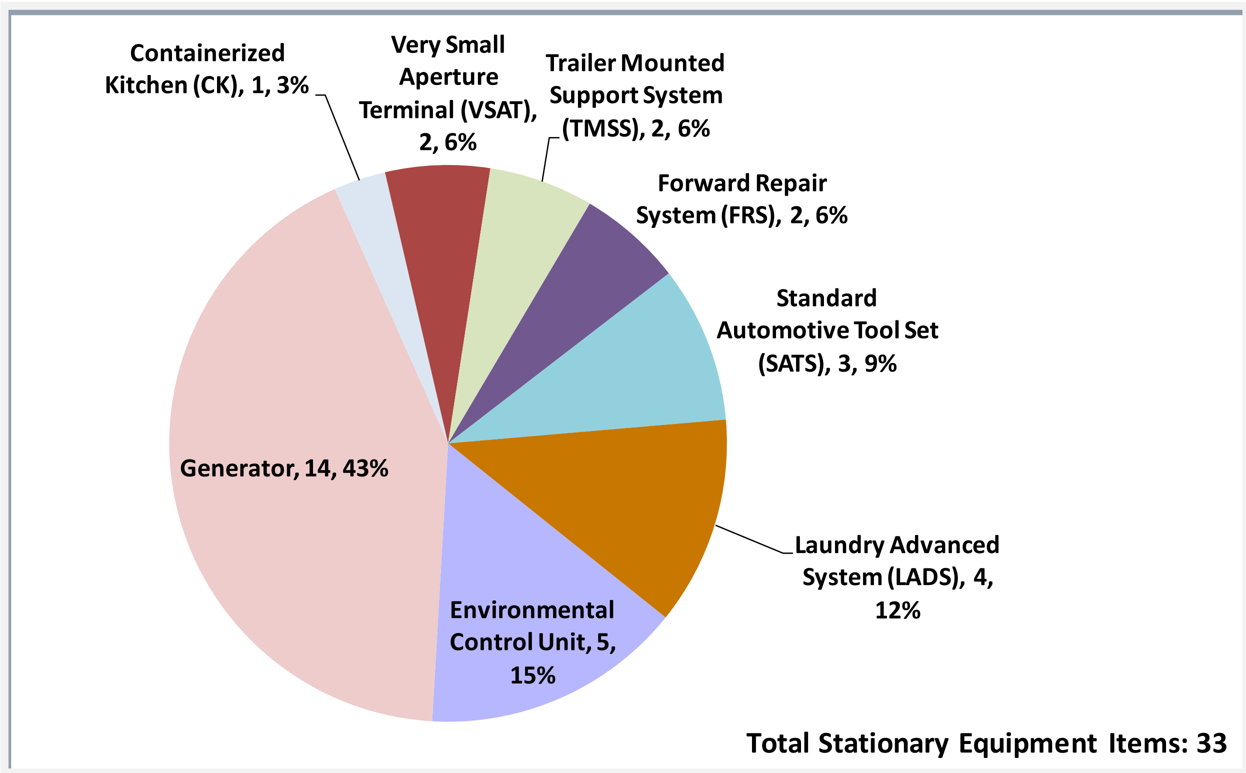


**Figure 2 • Types and Numbers of Stationary Equipment Items**

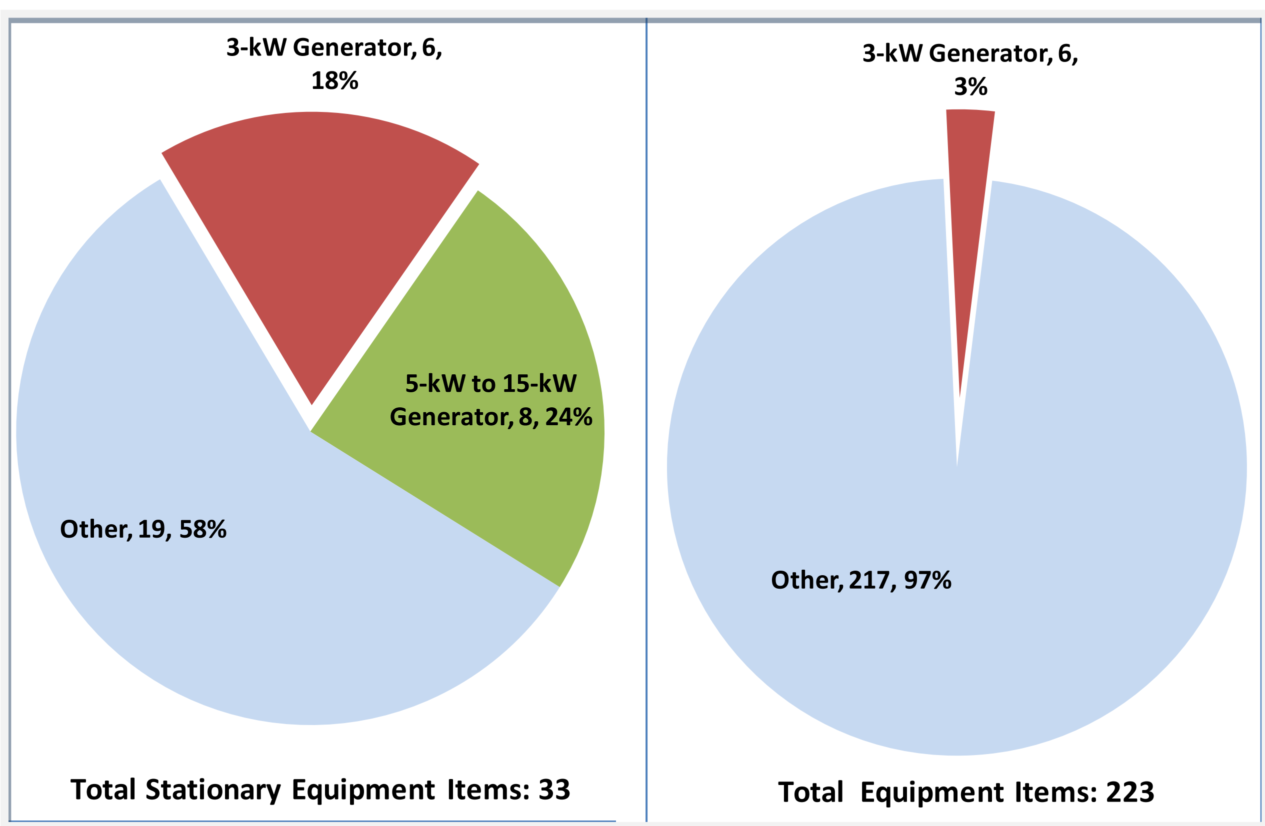


**Figure 3 • Equipment Items With Observed Negative Performance**

There is no way to know if the root cause of the issue with the small-scale mechanical fuel injection pumps could be partly or entirely attributed to the fuel. The condition of the generators, and the frequency of their operation prior to the demonstration is not known. The performance of their pumps, under the same exact duty cycle (generator load, ambient temperature, solar loading, etc.), may or may not be different when operating on other fuels such as typical (petroleum-based) JP-8 or even diesel fuel. However, it is reasonable to think that these pumps, under the same exact duty cycle, would perform the same, that is just as poorly, when operating on JP-8. This is because the chemical composition and properties of the HEFA SPK/JP-8 fuel blend are so similar to JP-8.

Table 3 provides a comparison, for some key properties, between the two loads of HEFA SPK/JP-8 delivered to Camp Grayling versus all the JP-8 batches procured by the Defense Logistics Agency worldwide during 2011. The properties for JP-8 are shown in terms of the minimum and maximum measured values, and the weighted mean values, across all batches. As the data in Table 3 shows, the property values for the HEFA SPK blends are very similar to the weighted mean JP-8, and they all fall within the range of values, or not far outside them, for each property found amongst all the batches of JP-8. In terms of qualifying the HEFA SPK blends for Army/DoD use in tactical generator sets, TARDEC is conducting more controlled testing to evaluate performance of fuel injection pumps and generators. In contrast, the evaluation at Camp Grayling was not controlled at all, and thus such an evaluation does not present the opportunity for a complete technical assessment. Nonetheless, this evaluation of the biofuel blend demonstrated at Camp Grayling is an important type of evaluation in the qualification of a drop-in fuel.

**Table 3 • Comparison of Some Key Properties for HEFA SPK Blends and JP-8**

| Property Description | | HEFA SPK/JP-8 Blend | | All JP-8 Batches Worldwide (DLA) | | |
|---|---|---|---|---|---|---|
| | | WO#001057 | WO#001071 | PQIS 2011 | PQIS 2011 | PQIS 2011 |
| | | FL-14477-12 | FL-14489-12 | Wt. Mean | Min | Max |
| **Property** | **Measurement** | **Result** | **Result** | **Result** | **Result** | **Result** |
| Distillation | IBP, °C | 156 | 160 | 152 | 90 | 195 |
| | 10% recovered, °C | 174 | 176 | 173 | 150 | 203 |
| | 20% recovered, °C | 182 | 183 | 180 | 162 | 207 |
| | 50% recovered, °C | 209 | 209 | 200 | 176 | 249 |
| | 90% recovered, °C | 262 | 263 | 242 | 201 | 291 |
| | FBP, °C | 272 | 273 | 267 | 219 | 311 |
| Flash Point | °C | 87 | 56 | 48 | 38 | 74 |
| Density | kg/L at 15°C | 0.774 | 0.774 | 0.804 | 0.781 | 0.837 |
| Viscosity | at -20°C, $mm^2/s$ | 5.1 | 5.1 | 4.3 | 2.8 | 7.2 |

## Comparisons of Performance (Diesel-to-Jet Fuel)

Jet fuel is an aviation-grade kerosene consisting of a distribution of hydrocarbons mostly in the $C_8$-$C_{16}$ boiling range. On the other hand, diesel fuel is a middle-distillate consisting of a distribution of hydrocarbons mostly in the $C_9$-$C_{23}$ boiling range. The variation in the composition of jet fuel and diesel fuel, most notably the prevalence of higher molecular weight $C_{17}$-$C_{23}$ hydrocarbons in diesel fuel but not jet fuel, is the reason these fuels are different. These differences in composition mean these fuels have different physical properties, and thus equipment that is operated on one or the other may have different performance. All of the Soldier feedback that focused on the differences they observed or perceived between equipment performance on jet fuel (the demonstration fuel) versus diesel fuel (their normal fuel) is attributable to the relationships between fuel properties and diesel engine (and fuel pump) performance. These relationships have been exhaustively studied and reported on over a number of years, and still are studied today. The discussion of the fuel property-engine performance relationships is outside the scope of this report.

# VI. CONCLUSIONS & RECOMMENDATIONS

The demonstration of the HEFA SPK/JP-8 fuel blend at Camp Grayling was successful in that throughout its duration, no significant or unexpected issues arose with vehicles or other equipment that operated on the biofuel. The annual summer training exercises of Army MING units conducted at the Joint Maneuver Training Center at Camp Grayling provided an excellent venue and opportunity to get fuel into the “hands of the user” to capture “real world” data and Soldier feedback.

# VII. REFERENCES

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2. Army Energy Security Implementation Strategy, January 13, 2009.
3. Air Force Energy Plan 2010.
4. A Navy Energy Vision for the 21st Century, October 2010.
5. "Army Announces "Green Warrior Convoy"", Office of the Chief of Public Affairs, April 11, 2012, http://www.army.mil/article/77592/Army_announces__Green_Warrior_Convoy_/.

# APPENDICES

# APPENDIX A

# List of TARDEC Reports on Evaluations of SPK (FT and HEFA) Blends

Table A-1 • List of TARDEC Reports on Evaluations of SPK (FT and HEFA) Blends

| Document Title | Date | Publication Sourcing | |
|---|---|---|---|
| | | DTIC | Other |
| Synthetic Fuel Lubricity Evaluations | Sep-03 | ADA421822 | Interim Report TFLRF No. 367 |
| Synthetic JP-5 Aviation Turbine Fuel Elastomer Compatibility | Nov-03 | ADA477802 | TARDEC Report No. 13978 |
| Exhaust Emissions From a 6.5L Diesel Engine Using Synthetic Fuel and Low-Sulfur Diesel Fuel | Dec-03 | ADA426513 | Interim Report TFLRF No. 370 |
| Alternative Fuels: Assessment of Fischer-Tropsch Fuel for Military Use in 6.5L Diesel Engine | Jan-04 | -- | SAE Paper No. 2004-01-2961 |
| Evaluation of Ball on Three Disks as Lubricity Evaluator for CI/LI in Synthetic JP-5 | Apr-04 | ADA462280 | TARDEC Report No. 13977 |
| Production and Characterization of Synthetic Jet Fuel Produced from Fischer-Tropsch Hydrocarbons | Aug-04 | -- | ACS Pre-print Paper |
| Composition of Syntroleum S-5 and Conformance to JP-5 Specification | Aug-04 | -- | ACS Pre-print Paper |
| Synthetic Fischer-Tropsch (FT) JP-5/JP-8 Aviation Turbine Fuel Elastomer Compatibility | Feb-05 | ADA477802 | TARDEC Report No. 15043 |
| Bench Top Lubricity Evaluator Correlation with Military Rotary Fuel Injection Pump Test Rig | Oct-05 | ADA524925 | SAE Paper No. 2005-01-3899 |
| Properties of Fischer-Tropsch (FT) Blends for Use in Military Equipment | Apr-06 | ADA521910 | SAE Paper No. 2006-01-0702 |
| Elastomer Impact When Switch-Loading Synthetic Fuel Blends and Petroleum Fuels | Jul-06 | ADA459513 | TARDEC Report No. 16028 |
| The Effect of Switch-Loading Fuels on Fuel-Wetted Elastomers | Jan-07 | ADA497968 | SAE Paper No. 2007-01-1453 |
| Evaluation of Synthetic Fuel for Army Ground Applications, Tasks II-VI | Jun-07 | TBD | Interim Report TFLRF No. 389 |
| Evaluation of Synthetic Fuel in Military Tactical Generators | Jun-08 | ADA482914 | Interim Report TFLRF No. 392 |
| Engine Durability Evaluation Using Synthetic Fuel, Caterpillar C7 Engine | Oct-08 | ADA494498 | Interim Report TFLRF No. 391 |
| Fischer-Tropsch Synthetic Fuel Evaluations: HMMWV Test Track Evaluation | Sep-09 | ADA509165 | Interim Report TFLRF No. 400 |
| Evaluation of the Fuel Effects of Synthetic JP-8 Blends on the 6.5L Turbo Diesel V8 from General Engine Products (GEP) Using the NATO Standard Engine Laboratory Test AEP-5, Edition 3, May 1988 | Dec-09 | -- | TARDEC Report, Distr A |
| Durability Evaluation of Two New Production Caterpillar C7 Engines Subjected to Elevated Temperature 400 Hour NATO Tests Fueled by JP-8 and 50%/50% Blend of JP-8 and S-8 | Feb-10 | -- | TARDEC Report, Distr E |
| Synthetic Fuel Blend Demonstration Program at Fort Bliss, Texas | May-10 | ADA533890 | Interim Report TFLRF No. 407 |
| Lubricity and Derived Cetane Number Measurements of Jet Fuels, Alternative Fuels and Fuel Blends | Jul-10 | ADA529442 | Interim Report TFLRF No. 405 |
| Cummins V903 Alternative Fuel Evaluation, NATO Modified Standard Laboratory Test AEP-5 | May-11 | ADA369316 | TARDEC Report, Distr D |
| Military Fuel and Alternative Fuel Effects on a Modern Diesel Engine Employing A Fuel-Lubricated High Pressure Common Rail Fuel Injection System | Aug-11 | ADA547468 | GVSETS 2011 Paper, Distr A |
| Evaluation of Military Fuels Using a Ford 6.7L Powerstroke Diesel Engine | Aug-11 | ADA560574 | Interim Report TFLRF No. 415 |
| Durability Evaluation of the Effects of Fischer-Tropsch Derived Synthetic Paraffinic Kerosene Blended Up to 50% With Petroleum JP-8 on a Detroit Diesel/MTU 8V92TA Engine | Dec-11 | ADA555387 | TARDEC Report, Distr A |
| Durability Evaluation of the Effects of Hydroprocessed Esters and Fatty Acids - Synthetic Paraffinic Kerosene (HEFA-SPK) Blended With up to 50% Petroleum JP-8 on a General Engine Products (GEP) 6.5L Turbo Engine | Aug-12 | pending | TARDEC Report, Dist D |

# APPENDIX B

## Properties of Demonstration Fuel

Table B-1 • Properties of HEFA SPK/JP-8 Fuel Blend – 1st Tanker Truck

| JP-8 Containing HEFA SPK IAW MIL-DTL-83133H (Table I plus Table B-II) | | | | | Sample ID WO#001057 FL-14477-12 |
|---|---|---|---|---|---|
| **Property** | **Measurement** | **ASTM D** | **Min** | **Max** | **Result** |
| Saybolt Color | | 156 | report | | +25 |
| Total Acid Number | mg KOH/g | 3242 | | 0.015 | 0.005 |
| Aromatics | vol % | 1319 | 8.0 | 25.0 | 5.6 |
| Sulfur, Total | mass % | 2622 | | 0.30 | 0.0026 |
| | | 4294 | | | not tested |
| Distillation | IBP, °C | 86 | report | | 156 |
| | 10% recovered, °C | | | 205 | 174 |
| | 20% recovered, °C | | report | | 182 |
| | 50% recovered, °C | | report | | 209 |
| | 90% recovered, °C | | report | | 262 |
| | FBP, °C | | | 300 | 272 |
| | Residue, vol % | | | 1.5 | 1.4 |
| | Loss, vol % | | | 1.5 | 1.4 |
| | 50% recovery gradient, °C | | 15 | | 1.4 |
| | 90% recovery gradient, °C | | 40 | | 34 |
| Flash Point | °C | 93 | 38 | | 87 |
| Density | kg/L at 15°C | 1298 | 0.775 | 0.840 | 0.774 |
| | | 4052 | | | 0.774 |
| Gravity | API at 60°F | 1298 | 37.0 | 51.0 | 51.2 |
| | | 4052 | | | 51.2 |
| Freezing Point | °C | 7153 | | -47 | -51.2 |
| Viscosity | at -20°C, $mm^2/s$ | 445 | | 8.0 | 5.1 |
| | at 40°C, $mm^2/s$ | 445 | | | 1.4 |
| Net Heat of Combustion | MJ/kg | 3338 | 42.8 | | 43.8 |
| | | 4809 | | | not tested |
| Hydrogen Content | mass % | 3343 | 13.4 | | 14.8 |
| Calculated Cetane Index | equation 1/equation 2 | 976 | report | | 60/59 |
| | | 4737 | | | 62 |
| Derived Cetane Number | | 6890 | 40 | | 54 |
| Copper Strip Corrosion | Rating (2 hr at 100°C) | 130 | | No. 1 | 1a |
| Thermal Stability | Change in press drop, mm Hg | 3241 | | 25 | 0 |
| | Heater tube deposit, visual rating | | | <3 | <1 |
| Existent Gum | mg/100 mL | 381 | | 7.0 | 0.4 |
| Particulate Matter | mg/L | 6217 | | 1.0 | 0.2 |
| Water Separation Index | at point of manufacture with AO, MDA, FSII and CI/LI | 3948 | 70 | | 86 |
| Fuel System Icing Inhibitor | vol % | 5006 | 0.10 | 0.15 | not tested |
| Fuel Electrical Conductivity | pS/m | 2624 | 150 | 600 | 15 |
| Lubricity (BOCLE) | Wear Scar Diameter, mm | 5001 | | | 0.45 |

Table B-2 • Properties of HEFA SPK/JP-8 Fuel Blend – 2nd Tanker Truck

| JP-8 Containing HEFA SPK IAW MIL-DTL-83133H (Table I plus Table B-II) | | | | | Sample ID WO#001071 FL-14489-12 |
|---|---|---|---|---|---|
| **Property** | **Measurement** | **ASTM D** | **Min** | **Max** | **Result** |
| Saybolt Color | | 156 | report | | 24 |
| Total Acid Number | mg KOH/g | 3242 | | 0.015 | 0.006 |
| Aromatics | vol % | 1319 | 8.0 | 25.0 | 6.0 |
| Sulfur, Total | mass % | 2622 | | 0.30 | 0.0021 |
| | | 4294 | | | not tested |
| Distillation | IBP, °C | 86 | report | | 160 |
| | 10% recovered, °C | | | 205 | 176 |
| | 20% recovered, °C | | report | | 183 |
| | 50% recovered, °C | | report | | 209 |
| | 90% recovered, °C | | report | | 263 |
| | FBP, °C | | | 300 | 273 |
| | Residue, vol % | | | 1.5 | 1.5 |
| | Loss, vol % | | | 1.5 | 1.6 |
| | 50% recovery gradient, °C | | 15 | | 34 |
| | 90% recovery gradient, °C | | 40 | | 88 |
| Flash Point | °C | 93 | 38 | | 56 |
| Density | kg/L at 15°C | 1298 | 0.775 | 0.840 | 0.774 |
| | | 4052 | | | 0.774 |
| Gravity | API at 60°F | 1298 | 37.0 | 51.0 | 51.2 |
| | | 4052 | | | 51.3 |
| Freezing Point | °C | 7153 | | -47 | -50.4 |
| Viscosity | at -20°C, $mm^2/s$ | 445 | | 8.0 | 5.1 |
| | at 40°C, $mm^2/s$ | 445 | | | 1.4 |
| Net Heat of Combustion | MJ/kg | 3338 | 42.8 | | 43.8 |
| | | 4809 | | | not tested |
| Hydrogen Content | mass % | 3343 | 13.4 | | 14.8 |
| Calculated Cetane Index | equation 1/equation 2 | 976 | report | | 61/59 |
| | | 4737 | | | 63 |
| Derived Cetane Number | | 6890 | 40 | | 53 |
| Copper Strip Corrosion | Rating (2 hr at 100°C) | 130 | | No. 1 | 1a |
| Thermal Stability | Change in press drop, mm Hg | 3241 | | 25 | 0 |
| | Heater tube deposit, visual rating | | | <3 | <1 |
| Existent Gum | mg/100 mL | 381 | | 7.0 | 0.9 |
| Particulate Matter | mg/L | 6217 | | 1.0 | 0.8 |
| Water Separation Index | at point of manufacture with AO, MDA, FSII and CI/LI | 3948 | 70 | | 83 |
| Fuel System Icing Inhibitor | vol % | 5006 | 0.10 | 0.15 | not tested |
| Fuel Electrical Conductivity | pS/m | 2624 | 150 | 600 | 7 |
| Lubricity (BOCLE) | Wear Scar Diameter, mm | 5001 | | | 0.53 |

# APPENDIX C

# Equipment Powered by Demonstration Fuel

Table C-1 • Detailed Breakdown of Equipment Types

| Equipment Item Description | | Qty |
|---|---|---|
| PM Aviation Systems: | | |
| MT3 Standard Aircraft Towing System | | 1 |
| PM Warfighter Information Network-Tactical: | | |
| Very Small Aperture Terminal (VSAT) | | 2 |
| Trailer Mounted Support System (TMSS) | | 2 |
| PM Joint Combat Support Systems: | | |
| Forward Repair System (FRS) | | 2 |
| Standard Army Tool System (SATS) | | 3 |
| PM Force Projection: | | |
| Crane 7.5T | | 1 |
| Forklift 10K | | 3 |
| Containerized Kitchen (CK) | | 1 |
| Laundry Advanced System (LADS) | | 4 |
| Tank and Pumping Unit (TPU) | | 1 |
| PM Mobile Electric Power: | | |
| Generator | 3-kW | 6 |
| | 5-kW | 1 |
| | 10-kW | 6 |
| | 15-kW | 1 |
| Environmental Control Unit | | 5 |
| PM Tactical Vehicles: | | |
| High Mobility Multipurpose Wheeled Vehicle (HMMWV)* | M997 | 8 |
| | M998 | 35 |
| | M1097 | 22 |
| | M1097A1 | 2 |
| | M1165 | 21 |
| | M1165A1 | 6 |
| M939 Truck Series | M923A2 | 1 |
| | M934 | 2 |
| | M934A2 | 3 |
| | M936A2 | 1 |
| Family of Medium Tactical Vehicles (FMTV) | M1078 | 10 |
| | M1078A1 | 10 |
| | M1078P2 | 8 |
| | M1087 | 1 |
| | M1088 | 1 |
| | M1088A1 | 7 |
| | M1089 | 6 |
| Medium Tactical Vehicle (MTV) | M1083 | 4 |
| | M1083A1 | 7 |
| Light Medium Tactical Vehicle (LMTV) | M1079 | 7 |
| | M1079P2 | 1 |
| Heavy Expanded Mobility Tactical Truck (HEMTT) | M978 | 8 |
| | M984 | 1 |
| | M984A2 | 2 |
| Line Haul Truck - M915 | | 7 |
| Palletized Load System (PLS) - M1075 | | 3 |

*includes one up-armored HMMWV variant