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# Evaluation of Procedures for Hand Blending Fuel Additives

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This paper details the evaluation of Fuels Technical Letter (FTL), FTL 15-02 (Change 1), for the field blending of additives in commercial jet fuel. The intent of this project is to quantitatively test multiple samples while following the procedures within the FTL to ensure the method spelled out in the FTL is sufficient to create a homogeneously additized fuel. In addition to ASTM D5006 (11) and ASTM D2624 (12) test methods specified in the FTL, ASTM D4176 and IP 564 were utilized to determine if the fuel additive droplets had been dispersed into the fuel. The particle count data was reported in accordance to ISO 4406 plus the 30 µm channel as established in MIL-STD-3004D with change 1.

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**U.S. Army Tank Automotive Research, Development and Engineering Center**
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# Evaluation of Procedures for Hand Blending Fuel Additives

**Joel Schmitigal**
**Force Projection Technology**

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## List of Tables

## List of Symbols, Abbreviations and Acronyms

| | |
|---|---|
| % | Percent |
| °C | Degrees Centigrade |
| °F | Degrees Fahrenheit |
| µm | micrometer (micron) |
| ASTM | ASTM International |
| CI/LI | Corrosion Inhibitor/Lubricity Improver |
| DFSP | Defense Fuel Support Point |
| DiEGME | Diethylene Glycol Monomethyl Ether |
| DLA-E | Defense Logistics Agency - Energy |
| DTL | Detail |
| FTL | Fuels Technical Letter |
| FSII | Fuel System Icing Inhibitor |
| GPM | Gallons Per Minute |
| HEMTT | Heavy Expanded Mobility Tactical Truck |
| HMMWV | High Mobility Multipurpose Wheeled Vehicle |
| ISO | International Organization for Standardization |
| JP-8 | Jet Propellant 8 |
| M | Meter |
| MIL | Military |
| ppm | Parts Per Million |
| PRF | Performance |
| pS | Picosiemens |
| SDA | Static Dissipater Additive |
| STD | Standard |
| UDRI | University of Dayton Research Institute |

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## Introduction

Military fuels differ from civilian fuels in that they are required to contain three fuel additives: fuel system icing inhibitor (FSII), corrosion inhibitor/lubricity improver (CI/LI), and static dissipater additives (SDA).

Fuel system icing inhibitors (FSII) are required to meet the requirements found in MIL-DTL-85470 (1). Diethylene glycol monomethyl ether (DiEGME) is the fuel system icing inhibitor required for use by current U.S. military fuel specifications (2) (3). Fuel system icing inhibitor, prevents undissolved water droplets from forming ice crystals which can clog aircraft fuel filters leading to engine fuel starvation. The majority of the Army's rotary aircraft fleet requires the use of FSII at low temperatures as they do not employ fuel system heat exchangers. The University of Dayton Research Institute (UDRI) determined that FSII levels at the 0.04% in fuel provide sufficient freeze protection, by concluding that the FSII is able to partition into a water phase at a ratio between 20% -70% in the presence of 120-130 ppm free water typically found in an aircraft fuel tank between 20°C and -47°C (4). FSII levels reduce the freezing point of the free water down to between -8°C and -59°C (4). An ancillary effect of FSII is its ability to inhibit microbial activity within fuel, at levels as low as 10% DiEGME in water (5). To its detriment FSII has also been linked to the formation of "apple jelly" contamination (6) and been blamed for top coat peeling of aircraft fuel tanks (4).

Rotary fuel pumps employed by several U.S. Army vehicles, including the Stanadyne injection pump used by the High Mobility Multipurpose Wheeled Vehicle (HMMWV), rely on fuel for lubrication, and are thereby highly sensitive to fuel lubricity. These rotary pumps were designed to operate on diesel fuel which has sufficient lubricity due to their high viscosity to keep moving parts from contacting one another. The use of low viscosity jet fuel increases the probability of wear between sliding parts, requiring the use of surface active corrosion improver lubricity improver (CI/LI) additives which create a film on the surface of metal parts for wear protection. Poor lubricity aviation fuels have been identified as causing premature fuel pump failures (7). The application of CI/LI additives has shown its effectiveness in increasing lubricity and providing for wear protection in low lubricity fuels (7). CI/LI additives are required to meet the performance requirements listed in MIL-PRF-25017 (8).

Static Dissipater Additive (SDA) is added to military aviation fuels to increase the electrical conductivity of the fuel thereby promoting the dissipation of static charge that can build up when the fuel is moved through the distribution system, particularly though restrictive fuel filtration systems. Stadis® 450 marketed by Innospec Fuel Specialties, LLC, is the only approved SDA at this time (3).

The U.S Army normally receives fuel procured by DLA-Energy (DLA-E) with these three additives already blended into the fuel. There are areas of operation where the supply chain is not mature or JP-8 is not available, which requires the Army to additize the fuel prior to use. When additive injectors are not available, the Jet A-1 fuel must be hand blended with additives to meet the specification requirements of JP-8.

In 2015, The Army Petroleum Center (APC) published a Fuels Technical Letter (FTL), FTL 15-02 (Change 1), for the field blending of additives in commercial jet fuel. The procedure within this letter was initially drafted in FY15 and found to provide insufficient additive blending, as identified by ASTM D4176 (9) and IP 564 (10), leading to the procedure to be further revised to allow for a more complete mixing.

The intent of this project was to quantitatively test multiple samples while following the procedures within the FTL to ensure the method spelled out in the FTL is sufficient to create a homogeneously additized fuel. In addition to ASTM D5006 (11) and ASTM D2624 (12) test methods specified in the FTL, ASTM D4176 and IP 564 were utilized to determine if the fuel additive droplets had been dispersed into the fuel. The particle count data was reported in accordance to ISO 4406 plus the 30 µm channel as established in MIL-STD-3004D with change 1 (13).

## Approach

### Fuel Additization Procedure

The Fuel Additization Checklist provided in Appendix A was utilized to ensure conformance with FTL 15-02 (Change 1). Steps 9 and 10 of the blending procedure found in the FTL were omitted during the evaluation to simulate a worst case scenario, per guidance from the Army Petroleum Center, where a second M978 is not available to perform the prescribed fuel transfer.

DLA-E arranged for 2500 gallons of JET-A fuel to be delivered to the Michigan Army National Guard Grand Ledge Armory with the fuel additives required per the FTL provided in separate fuel sample containers obtained from Defense Fuel Support Point (DFSP) Novi. With support from the Michigan Army National Guard, two M978 Heavy Expanded Mobility Tactical Truck **(**HEMTT**)** fuel tankers were available for this fuel blending evaluation. Truck A was staged with 540 gallons of F-24 fuel initially containing 0.04% FSII, with a conductivity of 47 pS/m. Truck B contained 2400 gallons of unadditized Jet A fuel with 0.00% FSII, a conductivity of 32 pS/m, and a particle count ISO code baseline of 14/12/8/4.

Fuel additives were prepared in accordance with Table 5 of FTL 15-02 (Change 1), as detailed in Table 1.

**Table 1. Additive volumes and blend ratios utilized in FTL evaluation.**

| Fuel Quantity Requiring Additives, Gallons | FSII required to achieve 1000 ppm (0.10%) | CI/LI required to achieve 15 ppm | Minimum Neat Fuel Required for Mixing CI/LI | SDA required to achieve 1.5 ppm | Minimum Neat Fuel Required for Mixing SDA |
|---|---|---|---|---|---|
| 2,500 | 2.5 gals | 143 ml | 143 ml | 14 ml | 266 ml |

Fuel additization was accomplished by utilizing the onboard pump and hose reel of Truck B to transfer the neat Jet A fuel to Truck A via the D-1 recirculation bottom load receptacle. The additives were added through the top hatch of Truck A in accordance with FTL 15-02 (Change 1), in order of SDA, CI/LI, and lastly FSII. All additives were dispensed into the M978 by the time that a total volume of 1225 gallons was obtained. A final volume of 2400 gallons of fuel was established in Truck A.

The fuel in Truck A was recirculated in accordance with FTL 15-02 (Change 1) via the M978's onboard pump and hose reel through the D-1 recirculation bottom load receptacle at a rate of 114 GPM, as reported via the M978's discharge gage. At 1000 gallons, an online particle count was initialized via sampling from the filter/separator fuel sampling port producing an ISO code of 14/10/7/3, indicating that all the additives has been disbursed within the fuel. The fuel was also visually inspected in accordance with ASTM D4176 and determined to be clear and bright (in accordance with procedure 1) and had haze rating of 1 (in accordance with procedure 2). Once the total volume of 2500 gallons of fuel was recirculated 3 samples were taken from the M978; all level, bottom, and top samples.

## Fuel Testing

The fuel was tested in accordance with ASTM D5006 and ASTM D2624 giving the results detailed in Table 2.

**Table 2. ASTM D5006, ASTM D2624, and ASTM D4176 data for All Level, Bottom, and Top Samples.**

| | ASTM D5006 | ASTM D2624 | ASTM D4176 (1) | ASTM D4176 (2) | Temperature |
|---|---|---|---|---|---|
| All Level Sample | 0.09% | 220 pS/m | clear and bright | 1 | 84°F (28.9°C) |
| Bottom Sample | 0.10% | 210 pS/m | clear and bright | 1 | 84°F (28.9°C) |
| Top Sample | 0.09% | 210 pS/m | clear and bright | 1 | 83°F (28.3°C) |

The fuel test data detailed in Table 2 in conjunction with the visual inspection and particle counter data collected at the 1000 gallons recirculated point indicate that the additives are appropriately disbursed in the fuel.

## Conclusions and Recommendations

The fuel additive blending procedure specified in FTL 15-02 (Change 1) was demonstrated to adequately blend fuel additives into neat Jet A fuel via hand additization and recirculation onboard a single M978 fuel tanker. It should be noted that the miscibility of the military additives into jet fuel may vary from base fuel to base fuel, so additive blending may not be achieved as quickly as observed during this evaluation. Additionally, hand blending done improperly can result in under or over additized fuels. For these reasons field additization should be discouraged unless absolutely necessary. Soldiers, should be trained to carry out the content found within the FTL on hand addition of jet fuels. Warfighters in the field should be provided the FTL as an instruction set when additized fuels are not obtainable, inline additive injection is not possible, and hand field additization is required.

Based on the field demonstration, TARDEC recommends the following updates to FTL 15-02 (Change 1):

- Specifically call out ASTM D5006 and ASTM D2624 to test FSII content and electrical conductivity, respectively,
- Add ASTM D4176, procedure 1 &2, for visual inspection.
- Include required blend ratios for dilutions of DCI-4A 50/50 and DCI-6A 80/20, to ensure that proper amounts of CI/LI are added to the fuel. In 2017, dilutions of DCI-4A and DCI-6A were approved and added to the MIL-PRF-25017 Qualified Products List (QPL).
- Proper levels of fuel turbulence is required to ensure proper blending, if a fuel pump is not able to maintain proper flow through the bottom load receptacle alternate methods of fuel recirculation should be investigated.

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## Appendix A

Fuel Additization Checklist

1. Ensure that both HEMMT tankers are empty. ____________
2. Inspect vehicles and ensure that all supplies, additives, personal protective equipment, and spill kits are on hand and serviceable.
   a. Begin with a pre-inspection and inventory of the vehicle and equipment. Drain any water from system, if necessary. ____________
   b. Ensure that all the equipment needed for operation is present and serviceable. ____________
   c. Ensure that the vehicle pumps are operational. ____________
   d. Ensure that the filters are serviceable. ____________
3. Test fuel in commercial tanker for for FSII. ____________
4. Transfer fuel from commercial tanker to HEMMT. ____________
5. Test fuel for FSII. ____________
6. Test fuel conductivity ____________
7. Test fuel temperature ____________
8. Test fuel particle count ____________
9. Measure and premix additives
   a. SDA 14 mL SDA - 266 mL fuel ____________
   b. CI/LI 143 mL CI/LI - 143 mL fuel ____________
   c. CI/LI 50:50 286 mL total ____________
10. Fill the tank with six inches of fuel, approximately 400 gallons for an M978. ____________
11. Continue to fill tank, pour the agitated premix(es) into the tank as it is beingfilled. Ensure all premix(es) are added to the tank by the time the tank is half full, approximately 1,125 gallons for an M978. ____________
12. Complete filling of the tank. ____________
13. IAW the operator’s manual, recirculate at least 1 time the rated capacity of the tank. ____________
14. Particle count from sample port during recirculation ____________
15. Once recirculation is completed, drain water from the filter separator. ____________
16. pull an all-level sample for testing of FSII and Conductivity ____________
17. Test FSII level ____________
18. Test conductivity ____________

IF REQUIRED

19. Circulate fuel
20. IAW the operator's manual, recirculate at least 1 time the rated capacity of the tank. ____________________
21. Particle count from sample port during recirculation ____________________
22. Once recirculation is completed, drain water from the filter separator. ____________________
23. pull an all-level sample for testing of FSII and Conductivity ____________________
24. Test FSII level ____________________
25. Test conductivity ____________________

IF REQUIRED

26. Transfer entire quantity of fuel into another tank vehicle ____________________
27. Particle count from sample port during recirculation ____________________
28. Once recirculation is completed, drain water from the filter separator. ____________________
29. pull an all-level sample for testing of FSII and Conductivity ____________________
30. Test FSII level ____________________
31. Test conductivity ____________________

IF REQUIRED

32. Recirculate 1 time the rated capacity of the tank IAW the operator's manual ____________________
33. Particle count from sample port during recirculation ____________________
34. Once recirculation is completed, drain water from the filter separator. ____________________
35. pull an all-level sample for testing of FSII and Conductivity ____________________
36. Test FSII level ____________________
37. Test conductivity ____________________

0.07-0.10 Vol% for FSII and 150-600 pS/m
Additional recirculation or transfer if required.