PRESENTATION OF A TEST SERIES CONDUCTED ON ACES II MIL (704 MIL) DIESEL FUEL CATALYST/ADDITIVE IN COMPLIANCE WITH THE PROCEDURES AND POLICIES OF THE U.S. ARMY MOBILITY TECHNOLOGY CENTER – FORT BELVOIR, VIRGINIA

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THE U.S. ARMY'S EVALUATION
PROCEDURE FOR FUEL ADDITIVES

Over the past years, the United States military forces have been approached by numerous aftermarket additive companies (fuel and additives) which were making several advertising claims regarding their additive's performance. None of them presented technical data standard laboratory, components, or engine tests that would enable one to make a judgment as to the product's capabilities.

Therefore, the Fort Belvoir Center (the "Center"), acting as DOD (Dept. of Defense) Executive Agent for Ground Fuels and Lubricants, has developed a series of screening tests, to be conducted by acceptable standardized laboratories, with specified procedures and include engine tests which enables one to objectively assess whether (1) the advertised performance improvement claims can be partially or fully verified, and (2) any adverse side effects will occur with potential use of the additive due to its possible incompatibility with other ingredients already present in the formulated fuel or lubricant products routinely procured by the Defense Logistics Agency.

These initial screening tests are to be paid by the additive manufacturer (or distributor). Once the additive "passes" specific tests required, Fort Belvoir Center then will go to the next phase conducting system-oriented evaluations on the candidate additive, and eventually the development of a purchase description/specification allowing the additive to be utilized with the Army's ground fleet (or any other DOD forces). This process assures that Army resources will only be used on those aftermarket additives that truly possess technologies worthwhile pursuing.

THE ACES II MIL (704/MIL) DIESEL FUEL CATALYST

American Clean Energy System's (ACES) military catalyst/additive products has modified its base diesel/fuel additive (after this named "catalyst") formulation to meet the specific diesel fuel specifications used by the U.S. Defense Forces. DF-2 (U.S. Military diesel) fuel is of a higher grade than that of the common commercial diesel fuel specifications. Refineries, when processing DF-2 grade diesel, have to meet the specific military requirements which include certain characteristics (pour point depressant, specific sulfur contents, etc).

Another issue is that numerous military divisions don't use their diesel powered equipment on a regular or daily basis, so the fuel is stored for long periods of time, and in several circumstances, the equipment is exposed to sand, extreme whether conditions, high humidity etc. ACES has modified the base formulation to adjust the ratio of fuel preservative (for longer storage capability), Biocide (to fight and eliminate fungi, bacteria, and yeast growth), provide top cylinder lubrication (to handle contamination and adverse side effects from sand and extreme environment conditions), and the ratio of the ignition improver – to provide easier starting (especially when engine is cold and in the battlefield for faster mobility and acceleration response), and other various modifications. This formula is coded ACES II MIL".

TESTS CONDUCTED ON ACES II MIL PURSUANT TO FORT BELVOIR CENTER'S PROCEDURES AND POLICIES

The Center has developed two sets of tests – laboratory tests to evaluate the catalyst's properties and compatibilities, and engine tests – to determine the engine performance and any side effects the the formula may have on engine performance, wear and emissions.

The first set of tests looks for any changes the catalyst may have on the chemical composition of the base DF-2 fuel, and any specification improvements the formulation may have to support the manufacturers claims.

The following sections describe each specific test, the results – both related to the formulas stability, its improvement features, and its effect on engine performance, reliability, maintenance effect and emissions.

It should be noted that in summary, ACES II MIL (704/MIL) "passed" all the minimum performance requirements while having several improving benefits in several areas and has proven not to have any adverse effect on actual engine tests and/or to the base fuel's chemical composition.

All of the tests conducted on ACES II MIL were conducted by Southwest Research Institute ("SwRI") in San Antonio, Texas. SwRI is the largest and most reputable fuel testing laboratory in the world. Similarly, SwRI is the laboratory in which Fort Belvoir Research Center is located and is a major contractor of various military testing and research programs.

THE INITIAL FUEL'S CHEMICAL SPECIFICATION TESTS

Attached hereto is a summary of 18 various tests conducted by SwRI's Engine, Fuel and Vehicle Research Division. These tests were conducted on DF-2 base diesel fuel – first without the formula ("NEAT") and then followed by the same procedure; i.e., the same DF-2 base fuel with the addition of ACES II MIL at a ratio of 1:1000 (i.e., one gallon by volume of ACES II MIL to 1000 gallons by volume of DF-2).

The following are the results of the initial tests as reported by SwRI:

TEST	METHOD	DF-2	DF-2 + ACES II MIL
API Gravity (at 60° F)	D 287	35.00	35.00
Cloud Point	D 2500	-18° C	-18° C
Pour Point	D 97	-21° C	-21° C
Kinematic Viscosity (40° C)	D 44	2.959	2.938
Distillation (° F):	D 86		
Initial Boiling Point		382	382
Mid Point		518	519
End Point		632	633
Carbon Residue (10% bottom)	D 524	0.12	0.11
Sulfur	D 2622	0.114%	0.110%
Copper Strip Corrosion	D 130	1A	1A
Ash	D 482	0.01	0.01
Accel. Stability (mg/100ml)	D 2274	0.8	0.8
Neutralization No.:	D 974		
Total Acid No.		0.07	0.07
Total Base No.		< 0.01	< 0.01
Particulate Contamination	D 2276	0.93	0.58
Cetane No.	D 613	43.6	45.3
Carbon	D 5291	86.93	86.62
Hydrogen	D 5291	12.97	13.19
Nitrogen	D 5291	< 0.1	< 0.1
Oxygen	D 5291	< 0.1	< 0.1

The following are the fuel specifications that were NOT changed by the addition of the ACES II MIL:

1) API Gravity;
2) Cloud Point;
3) Pour Point;
4) Copper Strip Corrosion;
5) Ash;
6) Accelerated Stability;
7) Neutralization Total Acid;
8) Neutralization Total Base;
9) Nitrogen Content; and
10) Oxygen Content.

The following are the fuel specifications that DID change by the addition of ACES II MIL:

1) Kinematic Viscosity (40° C): From 2.959 to 2.938;
2) Distillation Mid Point (50%): From 518° F to 519° F;
3) Distillation End Point: From 632° F to 633° F;
4) Carbon Residue (10% bottom): From 0.12 to 0.11;
5) Sulfur Content: From 0.114% to 0.110%;
6) Particulate Contamination: From 0.93 to 0.58;
7) Cetane No.: From 43.6 to 45.3;
8) Carbon Content: From 86.93 to 86.62;
9) Hydrogen Content: From 12.97 to 13.19.

Some of these changes are minor, and some are significant. In the following section, each result will be presented with an explanation as to the meaning of each "change" and what effect, if any, each change could potentially have on the engine's performance.

SPECIFIC CHANGES IN THE DF-2'S PROPERTIES DUE TO THE ADDITION OF THE ACES II MIL CATALYST

1. Kinematic Viscosity

This test's purpose is to determine the fuel's flow rate. The *Kinematic Viscosity* is determined by measuring the time for a volume of liquid to flow under gravity through a calibrated glass capillary viscometer.

The result of this test is represented by a "cSt" number. The lower the number, the higher volume of fuel flows through the system.

The SwRI test shows that the ACES II MIL reduced the cSt number (from 2.959 to 2.938). This indicates that the addition of ACES II MIL does, in fact, improve the fuel's flow which can be "significant" in cold weather.

2. Distillation

The changes caused by the use of the ACES II MIL on the distillation curve of the base DF-2 fuel are VERY MINOR. A change of one degree (1° F) is not significant. 1-3° F can be within the "margin of error" category. However, the DF-2 fuel requirements provide a certain range of distillation at each specific percentage. The range "ALLOWED" varies from 60 to 80° F. For example, the "legal" range for a 2-D fuel is as follows:

IBP° F (Initial Boiling Point)	–	340-400
50% °F, (Mid-Point)	–	470-540
EP °F (End-Point)	–	610-690

The SwRI test shows that the addition of the ACES II MIL did NOT create any adverse effect on the distillation curve and the minor "change" is well within the variation range of the "permitted" temperature. Mid-Point (50%) was changed from 518° F to 519° F. End-Point was changed from 632° F to 633° F. Accordingly, the presence of the ACES II MIL in the base fuel did not cause any significant change which could cause any adverse effect to the distillation curve or to the fuel's volatility.

3. Carbon Residue (10% bottom)

In this test, SwRI determined that the blend containing the ACES II MIL produced LOWER Carbon Residue – from 0.12 of the base diesel fuel to 0.11 of the treated fuel. This represents a reduction of approximately 8%.

It has been well established that the Carbon Residue Diesel Fuel *"CORRELATES APPROXIMATELY WITH COMBUSTION CHAMBER DEPOSITS."*[1]

Accordingly, this test shows that by adding ACES II MIL to the DF-2 fuel, a reduction amounting to approximately 8% was noted. This can be significant in reducing deposits in the engine's combustion chamber area which will result in improving overall engine and combustion performance, reduced maintenance and increased engine life.

4. Sulfur Content

This test measures the concentration of sulfur weight/percent. Sulfur Oxides formed during combustion promotes rusting, corrosion and crankcase degradation. A certain amount of fuel works its way into the engine's crankcase, thus causing a higher sulfur content in the oil which results in more corrosion, rust, and metal deterioration.

The SwRI test shows that the addition of the ACES II MIL to the base DF-2 fuel REDUCED the sulfur level from 0.114% to 0.110%. This means a reduction of approximately 4.5% (i.e., using the Sulfur level of the base DF-2 as 100%).

This test result indicates that certain ingredients within the ACES II MIL can potentially reduce problems of corrosion and rust, reduce oil contamination and increase engine component life.

In addition, the lower the sulfur level of the fuel, the less sulfur will be released to the environment. Not all sulfur within the fuel can be burned, so any reduction is preferred.

5. Particulate Contamination

This method (ASTM D 2276) is designed to determine the particulate contamination of the fuel (mainly used in determining the contamination level in Aviation Fuel).

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[1] The "established concept that the ***... "Carbon Residue of diesel fuel correlates approximately with combustion chamber deposit"*** is mentioned in the ASTM D 524-88 Procedure under Title 4 "Significant and Use" section – page 205. This test method has been adopted for use by government agencies to replace Method 5002 of Federal Test Method Standard No. 791b.

The SwRI test shows a REMARKABLE AND CONSIDERABLE reduction in Particulate Contamination level when the ACES II MIL was added to the DF-2 base fuel (from 0.93 to 0.58). This translates to a REDUCTION of approximately 37%!

The reduction in the level of particulate contamination in the blend containing the ACES II MIL is SIGNIFICANT. It is well established that particulate contamination has a DIRECT impact on filter plugging and other operational problems, including fuel injector clogging, injector pump wear, build-up in the valve train, tops of the piston, etc. The higher the particulate contaminant level is – the more unburned particulates will be released from the exhaust system.

This test demonstrates the ability of the ACES II MIL to "dissolve" particulates in the base fuel which can reduce maintenance costs and downtime substantially, extending engine life and reduced emissions.

6. Cetane No.

Cetane Number is the most used "word" in describing diesel fuel's quality. Like gasoline's Octane – CETANE is the number used in Diesel fuel.

Cetane Number is determined by the fuel's combustion performance. This test is performed on a CFR engine which closely simulates the actual combustion chamber of a commonly-used diesel engine.

In general, determination of the fuel's quality, the higher Cetane number of the diesel fuel – the better combustion performance can be achieved. Some of the potential improvements of combustion performance are:

1) Easier start;
2) Increased power;
3) Better acceleration response and stability;
4) Reduced emissions;
5) Improved fuel efficiency;
6) Less combustion by-products.

SwRI test shows that the addition of the ACES II MIL to the DF-2 base fuel (in a ratio of 1:1,000) BOOSTED THE CETANE NUMBER FROM 43.6 TO 45.3 (1.7 points – about 3.9%).

7. Carbon Content and Hydrogen Content Tests

The Carbon and Hydrogen content of the fuel is determined by test method D 5291. In this method, the mass percentage of the Hydrogen and Carbon are measured.

In this test, SwRI determined that the addition of the ACES II MIL to the DF-2 fuel resulted in a reduction of Carbon content (from 86.93 to 86.62) and an increase in the Hydrogen content (from 12.97 to 13.19).

The known Hydrogen content of fuel is helpful in addressing the fuel's performance characteristics. Hydrogen-to-Carbon ratio is an essential aspect in performance of the fuel (i.e., by increasing the ratio's gap).

Increasing the Hydrogen level while reducing the Carbon level is a significant achievement.

THE SECONDARY (AND FINAL) ENGINE TESTS

The following two tests are engine tests. The first is called the Caterpillar 1-K test, and the second is called the Series 60 Engine – Emission Test.

A. THE CATERPILLAR 1-K TEST

This test, using a 1Y540 Caterpillar single-cylinder engine, was initially designed to determine the acceptability of oils in run in Caterpillar engines. In our situation, since we offer a fuel catalyst/additive (and not oil additive), the test was conducted using standard military test specs. Oil reference # (TMC-809-1) and the ACES II MIL fuel formula was added to the base military spec test fuel (Howell RDF-6, Batch 95-5) at a ratio of 1:1000 (vol./vol.). The duration of the test was 252 hours.

The acceptability of the oils and/or fuel catalyst are based on initial and final oil consumption, and measurements that include piston deposit levels, piston ring projection and wear, liner polish and wear, and oil deterioration.

The result of the tests are submitted in tables and graphs in the following categories: BSOC, TLHC, WDK and TGF (details of the results of each group are presented in the following test results section). In addition, a physical inspection of the components is conducted and evidence of it's properties are photographed showing the condition of the piston, rings, and cylinder liner.

1-K TEST RESULTS USING ACES II MIL

1) BSOC: This measurement is to determine the total oil consumption for the entire 252 hour test duration. Oil scale reading is measured every hour, and every 12 hours oil is added to return the scale system to the initial level. Each 12 hours, data point is plotted and an average is calculated for the duration of the test. The maximum oil consumption permissible for passing the test is – 0.5 g/kw-hr.

At the beginning of the ACES II MIL test (0 hour), the oil consumption was at 0.34. The lowest consumption point was at approximately 48 hours where a measurement of 0.16 was recorded and the highest point of approximately 0.28 at about 210 hours. The average oil consumption using ACES II MIL was 0.22. This figure is 11.11% LOWER than the recorded average best results previously recorded (see page 10). As mentioned above, the "passing" limit for the test is a maximum 0.5 g/kw-hr and ACES II MIL average oil consumption was lower than expected and definitely below the maximum consumption allowed (i.e., less than half of the allowed oil consumption).

2) TLHC: Carbon on the lands is limited to heavy and lights. Heavy land carbon is carbon which has more buildup compared with adjacent or land surface and has a polished or rubbed finish. Light land carbon is any other carbon deposit. Top land heavy carbon is the percent of heavy carbon found only on the side surface area of the piston above the top ring groove and below the piston crown. It is measured and calculated using a 20 segmented rating template and totaling the numbers of each of the segments to provide an estimated percent.

0% = CLEAN, and 100% = complete coverage (dirty). The maximum TLHC allowed in passing this test is 4%.

The TLHC measured in the ACES II MIL test was 0% (i.e., CLEAN). See notations on pg# 10,11,12

3) WDK: A measurement of weighted total deposits in several important zones pre-established. The weighted total deposit (WDK) rating is the sum of the zone demerit ratings multiplied by their respective location factors. The WDK rating for pistons is suitable for use as a laboratory test numerical passing limit. The maximum WDK passing limit is 315.3.

In this test, the WDK rating in the fuel treated with ACES II MIL was 202.1. This number is approximately 1/3 lower than the maximum deposit allowed for passing the test. The WDK of the ACES II MIL treated fuel was also lower than the lowest base 809-1 WDK which is 216.4. The ACES II MIL treated fuel provided 14.3 reduction in total WDK. See Table on page 3 and graph on page 17.

4) TGF: Piston groove deposits are generally difficult to assess because of deposit surface contours. The back clearance is the space between the back side of the ring and the back side of the groove when the ring is compressed, as in the cylinder and considered to be concentric with the piston. The percent of carbon fill is estimated while moving around the groove using a 20 segmented rating template. Totaling the number for each 20 segments will provide the estimated percent volume carbon fill of "Top Groove Fill" (TGF). To pass this test, the maximum TGF allowed is 22%. It is part of the est to provide an adjusted reduction of 4% of the gross figure (for residual fuel, ring expansion, etc.)

When fuel treated with ACES II MIL was tested, the GROSS TGF % was 15 and the adjusted figure was 11%. See summary Table on page 3. Also, see Graph on page 18 The adjusted figure of 11% is HALF of the TGF % allowed (i.e., 22%) to pass the test.

SUMMARY OF 1-K TEST

Since ACES II MIL provides top cylinder lubrication, we believe that the true TGF % is much lower for this reason that in the test, any residual top cylinder lubricant released by ACES II MIL is included in the total groove fill. The evidence of the synthetic form of top cylinder lubricant is noticed by the photographed and physical examination of the piston and cylinder liner; the fact that no measurable scarring is noticed after 252 hours of the high load test operation; and the noticeable improvements shown during and at the completion of the test period.

ACES II MIL's claims of ignition improvers, detergents, and rust inhibitors, are supported by the overall success of the tests conducted by SwRI, and the remarkable results when compared to the established "successful" figures.

The physical inspection and the photographs to the factual data clearly supports ACES performance claims.

Please note the last photos attached show the condition of a piston from a different 1K test and the type of damage occurring to such piston when the product tested is unacceptable.

B. ENGINE EMISSION TEST

In this test, conducted on a 1991 ODC Series 60 engine, when operation conditions are controlled, the % total smoke emissions are measured at three conditions: (1) during Acceleration ("ACCEL"); (2) at cruise conditions ("LUG"); and (3) at peak usage ("Peak").

The test was conducted first on base diesel fuel and then on the ACES II MIL treated fuel (at a ratio of 1:1000 – vol./vol.).

The test results showed that the fuel treated with ACES II MIL in all three conditions – the % of smoke emissions was REDUCED by at least 6% and by 36% at the best.

Filterability and Flash Point Tests

Flash Point: In this test, the diesel base fuel had a flash point of 167° F and with the catalyst, the Flash Point was slightly reduced to 162° F. The 5° reduction is apparently caused by the ignition improver contained in the ACES II MIL, but at the same time, it does not reduce it too low – and accordingly, the storage, handling and emergency fire procedures will remain the same.

Filterability: In this test, the fuel (with and without the formula) was tested for its filter blocking tendency. The results show the quantity of fuel (ml.) that passes through the filter at a specific pressure and period. This test shows that ACES II MIL did not cause any filter flow reduction (a problem that can occur when using thick or polymeric additives).

A copy of the Filter Blocking Tendency test conducted by SwRI is attached.

If you have any questions or need additional information, please feel free to contact me.

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