JP-8
THE SINGLE FUEL FORWARD

AN INFORMATION COMPENDIUM

U.S. Army Tank-automotive and Armaments Command
Research, Development, and Engineering Center
Warren, MI 48397-5000

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- FORWARD -

This Information Compendium is updated periodically to include new and relevant information pertaining to aviation kerosene turbine fuel with emphasis on its use in ground vehicles and equipment.

Questions as to the availability of referenced documents, publications, or even the availability of the Information Compendium itself should be directed to the address given below.

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INFORMATION PAPER

ON

AVIATION TURBINE AND

DIESEL ENGINE FUELS

INFORMATION PAPER

SUBJECT: Aviation Turbine Engine Fuels

PURPOSE: To provide information on JP-8, JP-5, and JET A-1 Aviation Turbine Fuels and indicate sources where these fuels can be obtained for testing purposes.

FACTS:

- MIL-DTL-5624 describes one grade of aviation turbine engine fuel; JP-5 a kerosene fuel. Previous revisions contained an additional grade, JP-4 which was a wide-cut fuel. Where prevailing low temperatures warrant a fuel with very low temperature operability, use of JP-4 is recommended.

- JP-4 is essentially a 50:50 mixture of heavy naphtha fraction (like gasoline) and kerosene. This fuel is not considered to be an acceptable substitute/alternate for diesel fuel. JP-4 is interchanged within NATO under NATO Code Number F-40. JP-4 is mainly procured as ASTM D 975 Jet B (or perhaps as CAN/CGSB 3.22). The chief difference between JP-4 and Jet B is that JP-4 contains the three mandatory additives while Jet B does not unless requested during procurement.

- JP-5 is a 100% kerosene blend and <u>is</u> <u>an</u> <u>acceptable</u> substitute/alternate for diesel fuel. JP-5 is interchanged within NATO under NATO Code Number F-44.

- MIL-DTL-83133 describes one grade of aviation turbine engine, JP-8.

- JP-8 is a 100% kerosene blend and <u>is</u> <u>an</u> <u>acceptable</u> substitute/alternate for diesel fuel. JP-8 is interchanged within NATO under NATO Code Number F-34.

- Both JP-5 and JP-8 are essentially the same type of fuel but only differ primarily in their flash point minimum requirements —
  - JP-5 specifies a 60°C (140°F) minimum requirement.
  - JP-8 specifies a 38°C (100°F) minimum requirement.

- The higher flash point requirement for JP-5 is due to the U.S. Navy's shipboard safety requirements.

- Recently completed survey on JP-8 and JP-5 fuels being suggested under contract worldwide provided following averaged properties —
  - JP-5 fuels had average flash point of 62°C (144°F).
  - JP-8 fuels had average flash point of 46°C (115°F).

- This difference in flash point requirements translates to very subtle difference in the physical and chemical characteristics when comparing JP-5 to JP-8; e.g., the average viscosity at 100°F is approximately 1.5 cSt as compared to approximately 1.3 cSt for JP-8.

- ASTM D1655 JET A-1 is the commercial industry standard for aviation fuel and is available worldwide. JET A-1 is essentially identical to JP-8 except that it does not necessarily contains the three additives required in JP-8. The three additives **mandatory for JP-8** are —

    - **Fuel System Icing Inhibitor (MIL-DTL-85470)**
    - **Corrosion Inhibitor (MIL-PRF-25017)**
    - **Static Dissipator Additive**

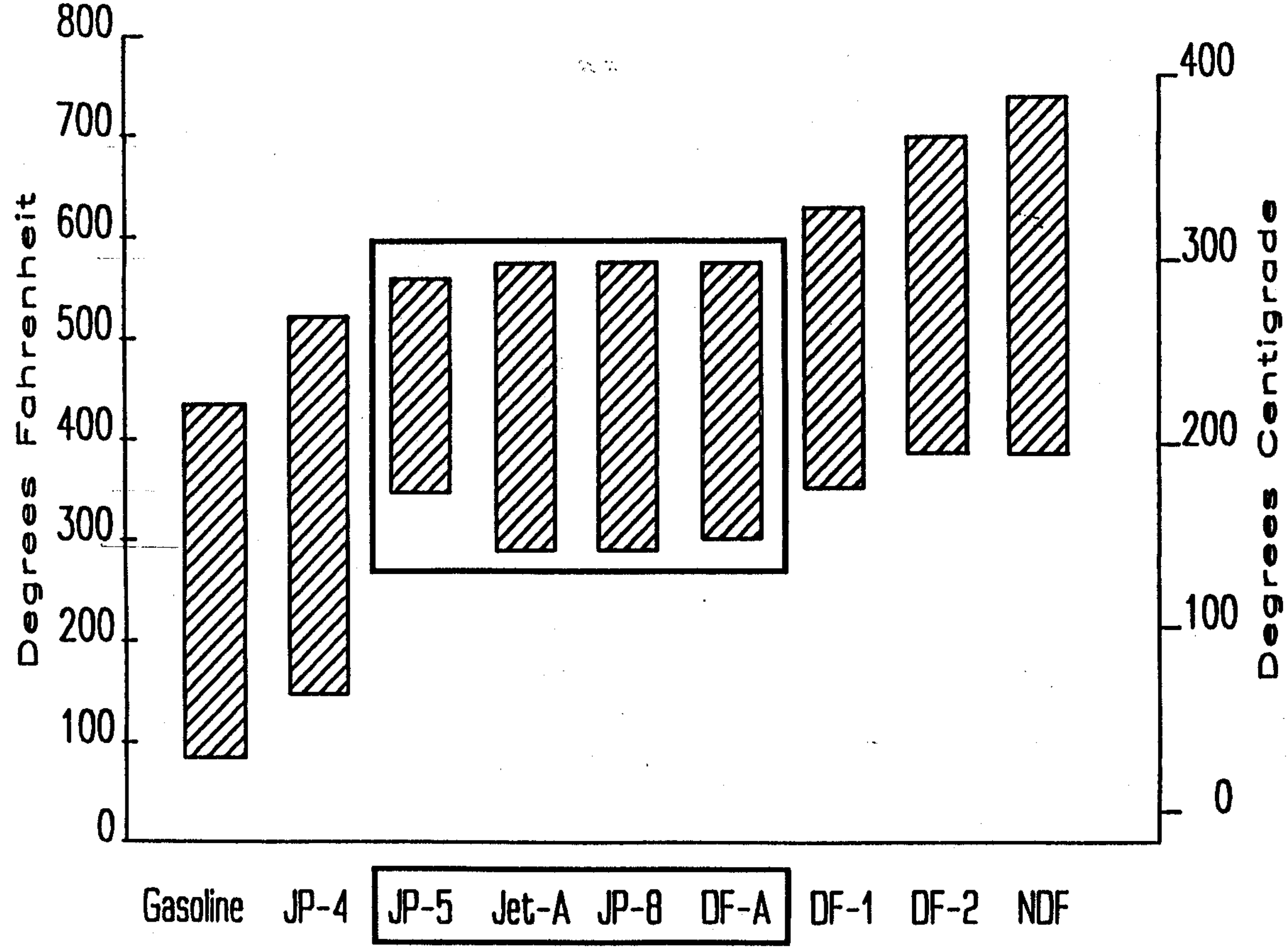
- ASTM D1655 also includes a JET A which is the industry standard for commercial aviation turbine fuel used only within the U.S. for domestic flights. The sole difference between JET A-1 vs. JET A is in the freeze point requirement. JET A-1 specifies a -47°C (-53°F) minimum, whereas JET A specifies a -40°C (-40°F) minimum.

- JP-8 has since been identified as **the Single Fuel for the Battlefield**. Its availability for use in research, development and testing programs is therefore essential.

- Defense Energy Support Center (DESC) currently has contracts for supplying JP-8 to U.S. locations worldwide. Additional information on supply and procurement of JP-8 may be obtained by contacting the Defense Energy Support Center, ATTN: DESC-B (Bulk Fuels), 8725 John J. Kingman Rd., Suite 4950, Ft. Belvoir, VA 22060-6222; DSN 427-9304 or Commercial (703) 767-9304.

TABLES AND CHARTS

BOILING RANGES OF FUELS



FUELS DEFINITIONS

FUEL	SPECIFICATION	INTERCHANGED AS NATO CODE NO.	COMPOSITION	ADDITIVES REQUIRED
JP-4[1]	MIL-DTL-5624	F-40	50:50 MIX OF NAPHTHA &	YES
JET B	ASTM D1655	F-40	KEROSENE	NO/YES
JP-5	MIL-DTL-5624	F-44	KEROSENE	YES
JP-8	MIL-DTL-83133	F-34	KEROSENE	YES
JET A-1	ASTM D1655	F-35	KEROSENE	NO
JET A	ASTM D1655	NO	SAME AS JET A-1 BUT ALLOWS A -40°C MAX FREEZE POINT	NO
~~DF-A[1]~~	~~VV-F-800~~	NO	KEROSENE	NO

[1] As there is little demand for JP-4, it is mainly procured as ASTM D 1655 Jet B (or perhaps as CAN/CGSB 3.22). The chief difference between JP-4 and Jet B is that JP-4 contains the three mandatory additives while Jet B does not unless requested during procurement. Where very low ambient temperatures prevail, use of ASTM D1655 JET B is recommended. Likewise, DF-A has been cancelled as Federal Specification VV-F-800 and has been replaced with JP-8 as stated in the Commercial Item Description A-A-52557.

LISTING OF NSNs FOR AVIATION FUELS AND ADDITIVES

Fuel/Additive	Specification	Unit	National Stock Number
JP-8	MIL-DTL-83133	Bulk	9130-01-031-5816
JET A	ASTM D 1655	Bulk	9130-00-359-2026
JET A-1	ASTM D 1655	Bulk	9130-00-753-5026
JP-5	MIL-DTL-5624	Bulk	9130-00-273-2379
JP-4	MIL-DTL-5624	Bulk	9130-01-305-5596
JET B	ASTM D 1655	Bulk	9130-01-234-1737
Corrosion Inhibitor	MIL-PRF-25017	55-gal	6850-00-292-9780
FSII*	MIL-DTL-85470	5-gal	6850-01-057-6427
FSII	MIL-DTL-85470	55-gal	6850-01-089-5514
SDA**	None/ Octel Starreon	1-gal	6850-01-097-2060
SDA	None/ Octel Starreon	5-gal	6850-01-099-4015

*FSII - Fuel System Icing Inhibitor (High Flash Point)
**SDA - Anti-Static Additive (i.e., Static Dissipator Additive or Electrical Conductivity Additive)

National Stock Numbers are not available for quantities other than "bulk" since Defense Energy Support Center procures these fuels in bulk. Where situations occur that drum quantities are needed, Defense Energy Support Center procures in bulk and then has the product repackaged in drum quantities.

KEY PROPERTY COMPARISONS
FOR DIESEL & AVIATION TURBINE FUELS

PROPERTY	U.S. DF-2	NATO DF F-54	WINTER MIX F-65	JP-8 F-34	JP-5 F-44	JET B F-40	JP-8 DEMO FUEL FT. BLISS FEB 1989	JP-8 DEMO FUEL FT. IRWIN MAY 1989
GRAVITY, °API	34.5	38.3	41.9	45.4	41.1	55.3	41.9	37.9
VISCOSITY @ 40°C, cSt	2.8	3.0	2.2	1.2	1.5	0.56	1.6	1.7
NET HEAT OF COMBUSTION (CALC, Btu/gal)	(130,319)	(127,1776)	(125,457)	(123,138)	(125,270)	(118,124)	125,941	128,431
%LESS Btu/gal THAN DF-2	0	2.0	3.7	5.5	3.8	9.4*	3.3	1.4

* ESTIMATED

QUESTIONS AND ANSWERS ON USING JP-8 IN GROUND VEHICLES

ADDENDUM

This section on Questions and Answers on Using JP-8 in Ground Vehicles pages 12 to 21 has not been updated as this represented the historical information that was generated at the time following the Desert Shield/Desert Storm operation in the Middle East (1990-1991 time frame), and the completion of the JP-8 Demonstration at Ft. Bliss TX (completed in 1992). All of the information contained in the Answer portions of the individual Questions is still relevant and correct.

USE OF JP-8 FUEL IN GROUND EQUIPMENT

The following is a listing of questions with answers frequently raised regarding use of JP-8 fuel in diesel fuel consuming vehicles and equipment. These responses have been coordinated with the U.S. Army Tank-Automotive Command and Headquarters, U.S. Air Force.

a. **What is JP-8?**

Answer: JP-8 is a kerosene-type aviation turbine fuel. It is procured under MIL-T-83133 and is interchanged within NATO under NATO Code Number F-34.

b. **What is the difference between JP-8 and JET A-1?**

Answer: JET A-1 is essentially identical to JP-8 except it does not contain the three additives required in JP-8; namely, the fuel system icing inhibitor, corrosion inhibitor, and static dissipator additive. JET A-1 is the standard fuel used by all commercial airline companies worldwide, except within the U.S. where JET A is principally used. JET A-1 differs from JET A only in its lower freeze point requirement; i.e., -40°C (-40°F) versus –47°C (-53°F) for JET A versus JET A-1.

c. **What is the difference between JP-8 and JP-4?**

Answer: JP-4 is not a kerosene-type aviation turbine fuel, but instead is approximately a 40:60, 50:50, or 60:40 mixture of kerosene with naphtha (e.g., a gasoline-type blending stock). It is called a "wide-cut fuel". JP-4 is procured under MIL-T-5624 and has been interchanged-within NATO under NATO Code Number F-40. It is not usually considered as an acceptable substitute for diesel-fueled equipment. F-40 has been the standard aircraft fuel for NATO aircraft until 1986 when NATO nations agreed to the conversion from F-40 to F-34.

d. **What is the difference between JP-8 and JP-5?**

Answer: JP-5, like JP-8, is a kerosene-type aviation fuel. However, it differs from JP-8 in having a higher flash point specification requirement; that is, 60°C (140°F) minimum versus 38°C (100°F) minimum for JP-5 vs. JP-8. This fuel is used for all sea-based aircraft in lieu of JP-8 because of safety requirements for on-board aircraft carrier operation. JP-5 is procured under MIL-T-5624 and is interchanged within NATO under NATO Code Number F-44.

e. **What is the difference between JP-8 and diesel fuel?**

Answer: JP-8 is primarily a kerosene whereas diesel fuels are generally either a distillate blend, a distillate and kerosene blend, or a kerosene blend depending on the grade of diesel; i.e., DF-2, DF-1, or arctic grade diesel fuel (DF-A). In most instances, DF-A and some DF-1 fuels are essentially kerosenes which are very similar to JP-8 fuels.

f. **What was the basis for conversion from JP-4 to JP-8?**

Answer: The initial rationale for converting from JP-4 to JP-8 within NATO was twofold;: (1) aircraft battle damage data had shown that JP-8 was an inherently safer fuel (i.e., less susceptible to ignition and sustained fires) and (2) JP-8 in being essentially "identical" to JET A-1 would be commercially available worldwide. JP-4 is not available at most commercial airports.

g. **When was this conversion to JP-8 initially considered?**

Answer: The issue was initially raised within NATO in 1975. The actual ratification to convert from F-40 (JP-4) to F-34 (JP-8) for all military land-based aircraft occurred in April 1986.

h. **When did this conversion also consider the possible changeover from DF-2 to JP-8?**

Answer: With the introduction of the M1 Abrams Tank into NATO in late 1981, cold starting problems occurred due to the waxing of the standard diesel fuel used by all NATO countries which is interchanged under NATO Code Number F-54. This military diesel fuel was and continues to be the best "low temperature" diesel engine fuel available within the NATO countries as other commercial diesel fuels have considerably higher wax content. This fuel waxing problem initially affected the starting of M1s and other gas turbine powered ground equipment operated by U.S. Forces. The problem was temporarily resolved by blending all F-54 diesel fuel with either JP-8 or JP-5 as a means to reduce the waxing tendency. This blend, later termed the "M1 Fuel Mix", became a standardized procedure for the U.S. Army that was exercised from November through April annually since 1982. Other NATO countries later began to experience similar low temperature operability problems which prompted the standardizing within NATO on this fuel blend for winter operation; namely, NATO Code Number F-65 which is a 50:50 mixture of F-54 and either F-34 or F-44. With all NATO forces experiencing some degree of low temperature operability problems due to fuel waxing and cold starting, consideration was then given to standardizing on JP-8 which would allow the realization of a "one fuel forward" concept. This quickly became a NATO initiative and has been strongly supported by all NATO countries.

i. **Can diesel engines use JP-8?**

Answer: **Yes**. Using JP-8 is essentially no different than operating diesel engines on DF-A or DF-1, both of which are "kerosene-base" fuels.

j. **Can turbine engines use JP-8?**

Answer: **Yes**. Gas turbine engines were initially developed on a kerosene base fuel and therefore can accommodate all turbine fuels.

k. **Are there adjustments to make if JP-8 fuels are used in diesel engines?**

Answer: **No**. Most engines do allow for use of the three grades of diesel fuel DF-2, DF-1, or DF-A interchangeably without any adjustments being required. Because of the lower volumetric heat content of JP-8 (i.e., the Btu/gal value) compared to DF-2, some reduction of maximum engine power may occur; however, for part-load operations, the operation will adjust automatically by increasing the fuel flow (i.e., pressing the accelerator pedal/rack further).

1. **Will JP-8 run hotter?**

Answer: **No**. However, if diesel engines are <u>mechanically</u> adjusted (i.e., settings fixed for JP-8) to optimally use JP-8 100% of the time, switchings back to DF-2 may produce some overfueling at the "maximum throttle" setting which could cause excess smoke and, under the most extreme conditions, over-temperature.

m. **Will engines generate more exhaust smoke when JP-8 is used?**

Answer: **No**. From the limited data generated to date on monitoring exhaust emissions from laboratory engine tests, use of JP-8 tends to significantly <u>lower</u> the overall emissions and smoke levels.

n. **Will using JP-8 in lieu of diesel fuel give lower mileage?**

Answer: From laboratory testing (i.e., engine dynamometer tests) completed thus far, some increase in fuel consumption has been evidenced because of the approximately 2% difference in volumetric heat content; <u>however</u>, vehicle testing is required to <u>fully quantify</u> this apparent fuel consumption increase as any engine efficiency improvement realized with using JP-8 may offset this. Controlled field testing of selected representative combat and tactical vehicles is planned to quantify this question of fuel consumption increase.

o. **What is power loss?**

Answer: Most engine power generally equates to acceleration, maximum speed, peak torque speed, and horsepower output (e.g., draw-bar pull horsepower, gross brake horsepower, etc.). Any decrease in any of these is usually regarded as a "power loss".

p. **Is JP-8 "compatible" with diesel fuel system materials (e.g. fuel lines, filters, seals, etc.)?**

Answer: **Yes**. JP-8 is completely compatible as kerosene is generally blended with distillate fractions as part of the diesel fuel pool to lower the wax content as a means to "winterize" diesel fuels. There is no incompatibility with changeover from diesel fuel to JP-8.

q. **Can JP-8 be used in other equipment (i.e., combat service support, etc.) that has been designed to use diesel fuel?**

Answer: For a vast majority of all diesel fuel consumers, JP-8 can be substituted with no problems whatsoever. However, there are a few items within the inventory which have been identified thus far that will not function satisfactorily with JP-8. The Vehicle Engine Exhaust Smoke System (VEESS) on the M1 tank has been shown to not produce satisfactory smoke with JP-8. An effort has been recently initiated to develop a suitable fix, either mechanically or with a fuel additive to resolve this problem. Additionally, a few of the combat service support equipment (e.g., M1950 Squad Stove, M2 Burner, etc.) will not work with JP-8 since they were designed for gasoline rather than DF-2.

r. **Can new engines use JP-8 and not have warranty provisions become void?**

Answer: **Yes and No**. There has been no warranty issues raised with using JP-8 in "new" engines except for the General Motors Corporation's 6.2L which is the powerplant for the Commercial Utility Cargo Vehicle (CUCV) and High Mobility Multipurpose Wheeled Vehicle (HMMWV). The limitation on warranty provisions on this engine was initially identified with using JP-8 when the prevailing ambient temperatures were above 22°C (71°F). This limitation was proposed because the fuel injection pump manufacturer (Stanadyne) maintained that severe wear would result due to the JP-8's lower viscosity not providing sufficient lubrication. However, a rather severe field test was recently conducted at GM's Desert Proving Ground in Mesa, Arizona, involving three CUCVs, two being operated on JP-8. The 10,000 mile endurance test was conducted during the hottest time of the year and the vehicles were subjected to all modes of extremely severe duty vehicle operation. At the completion of this test, inspection revealed no pump wear whatsoever. This has questioned the validity of the warranty concern initially raised. This warranty issue is still under consideration.

s. **What problems have occurred to date in substituting JP-8?**

Answer: JP-8 "per se" has not been in widespread use. Therefore, no direct feedback can be provided as to how it performs in vehicles and equipment. However, all Army equipment operating in Alaska the past several years have been successfully using JET A-1 which easily meets the requirements for DF-A. No problems have been reported and CUCVs have been operating successfully year round on this JET A-1. Moreover, U.S. Marine Corps and Army vehicles and equipment have previously accepted JP-5 as an approved alternate fuel for diesel fuel consuming equipment. As was explained previously (see question d), JP-5 and JP-8 are very similar except for flash point minimum requirements and differing freeze points.

t. **Will JP-8 be used worldwide?**

Answer: Current plans call for the conversion from JP-4 to JP-8 worldwide. Regarding the parallel conversion from DF-2 to JP-8 for ground equipment, the conversion within NATO is expected to commence on or about FY1991 because of existing stocks of DF-2 remaining within the war reserves and those operational issues mentioned above that need resolution. However, U.S. operations within the United Kingdom have already converted from DF-2 and JP-4 to JP-5. SOUTHCOM intends to begin conversion to JP-5 no later than FY1990 for both air and ground equipment. CENTCOM has already been storing JET A-1 for aircraft and will now address conversion of its ground requirements against JET A-1. PACOM currently plans to begin a phased conversion to JP-8 in FY 1989.

u. **Are other nations using JP-8 as a ground fuel?**

Answer: **Yes**. France, United Kingdom, Norway, and Netherlands as well as the United States show NATO Code Number F-34 (i.e., JP-8) as an acceptable alternate for NATO Code Number F-54 (i.e., our DF-2). Other NATO nations are in process of completing engine component tests to confirm the suitability in using JP-8 for ground equipment.

v. **What is the "one fuel forward" concept?**

Answer: The one fuel forward concept means a single fuel is used in the forward area for fueling all ground and aircraft systems. Changing from DF-2 to JP-8 at this time will not allow full implementation of this concept as there still exists a small percentage of gasoline consumers (e.g., mobile power generators, some combat service support equipment, etc.) in the field. However, these gasoline consumers are expected to be phased out and eventually replaced with diesel fueled counterparts. The eventual implementation of this one fuel forward concept is viewed as a significant "combat multiplier" and will afford many significant logistical advantages.

w. **Can JP-8 be substituted in gasoline-consuming equipment?**

Answer: **Yes and No**. As stated previously (see question q), JP-8 can be used in a majority of soldier support equipment as those items generally allow for multifuel operation (i.e., able to burn gasoline, kerosene, etc.). However, JP-8 cannot be used in any gasoline fueled mobile power generator sets or any other hardware equipped with a gasoline fueled engine.

x. **Will diesel fuel continue to be used?**

Answer: **Yes**. Certain locations such as those within the U.S. are not at this time targeted for conversion from diesel fuel to JP-8. Because of the unknowns as to where hostilities can occur, vehicles and equipment will have to rely on host nation support or locally available fuels and therefore will have to use diesel fuel.

z. **Are there benefits in using JP-8 as a diesel fuel?**

Answer: **Yes**. There are numerous advantages. Since JP-8 is a more highly refined fuel than DF-2, it will cause the following major benefits automatically to be realized.

- Reduced engine combustion-related component wear.
- Reduced nozzle fouling/deposit problems in both diesel and gas turbine engines.

- Reduced potential for fuel system corrosion problems.
- Increased fuel filter replacement intervals.
- Reduced exhaust emissions and signature.
- Extended oil change intervals and filter replacement intervals.
- Reduced fuel related low temperature operability problems; eliminate fuel waxing.
- Reduced potential for microbiological growth problems in fuel tanks.
- Reduced water entrainment/emulsification problems in vehicle fuel tanks.
- Increased storage stability capability.
- Improved fuel/lubricant related cold starting.

aa. **Is JP-8 more volatile than diesel fuel?**

Answer: **Yes and No**. If one measures volatility using distillation and flash point values, JP-8 could be considered somewhat more volatile than diesel fuel as it has a lower "boiling" range (i.e., 143°C (290°F) to 304°C (580°F) versus 171°C (340°F) to 366°C (690°F) for JP-8 versus diesel fuel, respectively) when compared to diesel fuel. Further, the flash point minimum limits also reflect this small increase in volatility as the flash point minimum limits for JP-8 versus diesel (DF-2) are 38°C (100°F) and 52°C (133°F), respectively. However, both JP-8 and diesel fuel including JP-5 are considered as low volatility fuels when compared to either JP-4 or gasolines as the former fuels (i.e., JP-8/JP-5 and diesel fuel) have no vapor pressure values when subjected to the standard ASTM D323 Reid Vapor Pressure technique. For example, ASTM D323 values for JP-4 are normally 2.6 psi whereas gasolines range from an average 10.3 psi for summer blends to an average 14.2 psi for winter blends. Because of the absence of any Reid Vapor Pressure values, JP-8 is considered to be a "low volatility" fuel which is not subject to the same potential flammability hazards as is JP-4 or gasoline. The small differences in flash point and distillation are not considered to be significant relative to having JP-8 classified as a volatile fuel.

bb. **What is JET A-1?**

Answer: JET A-1 is the industry standard fuel for all commercial airline carriers worldwide. As noted above, JET A-1 becomes JP-8 with addition of the three (3) mandatory additives; Fuel System Icing Inhibitor, Corrosion Inhibitor, and Static Dissipator Additive.

cc. **Have there been any mayor problems with using JP-5 or JP-8 in ground vehicle/equipment?**

Answer: **No**. Previous testing conducted in the 1960s and 1970s by the U.S. Navy and more recently by the U.S. Army has demonstrated that either fuels provide acceptable performance. There are two exceptions however —

- Absence of adequate smoke when using JP-8 or JP-5 in on-board vehicle engine exhaust smoke systems (VEESS) of armored vehicles. The smoke which is produced does not have adequate persistence nor does it completely obscure vehicles. However, use of diesel fuel in the VEESS when operating armored vehicles in high temperature environments (32° – 35°C (90° - 95°F) or higher) such as found in Operation Desert Shield will produce similar limitations.

- Loss of full power performance on certain power-limited vehicles. Certain vehicles such as the M88 Recovery Vehicle which are already somewhat power limited with diesel fuel will experience additional loss of pulling power when using JP-5 or JP-8.

dd. **Can JP-5 or JP-8 be used in gasoline-fueled ground vehicles/equipment?**

Answer: **No**. Kerosene fuels cannot be used in any spark-ignition engine systems .

ee. **Are there any additives you can add to JP-8 or JP-5 to enhance smoke production when the fuel in introduced into the VEESS?**

Answer: **No**. There are no additives available to date that can enhance the smoke production qualities of JP-8 or JP-5 when these fuels are introduced into VEESS of armored vehicles.

ff. **Will using either JP-8 or JP-5 cause a significant increase in fuel consumption?**

Answer: **No**. From information generated to date, there has been no indication of a significant increase in fuel consumption being evidenced. One may anticipate a slight increase (i.e., 1-5%) as this is due to the lower volumetric heat of combustion (Btu/gallon) of JP-8/JP-5 when compared to diesel fuel.

gg. **Will using either JP-8 or JP-5 plug fuel filters on vehicles?**

Answer: **No**. Both JP-5 and JP-8 are inherently cleaner fuels when compared to diesel fuel and they will not therefore cause fuel filter plugging.

hh. **What causes filter plugging?**

Answer: Plugging of filters is caused by either high particulate contamination (i.e., dirt, insoluble particles, etc.), previously deposited fuel deterioration products (i.e., oxidized reaction products, insoluble gums, etc.), presence of microbiological organisms, emulsions produced by residual water bottoms in fuel tanks, or a combination of these.

ii. **Can either JP-8 or JP-5 be directly added to vehicles/equipment containing diesel fuel in their tanks?**

Answer: **Yes**. There is no problem as both JP-8 and JP-5 will instantaneously mix with the residual diesel fuel in the fuel tank.

jj. **Will using JET A-1 which does not normally contain the corrosion inhibitor cause wear in rotary-type fuel lubricated injection pumps.?**

Answer: **Yes**. Use of JET A-1 in moderate to high temperature ambients will cause wear in these types of fuel injection pumps.

kk. **What causes growth of microbiological organisms (i.e., bugs) in fuel?**

Answer: Microbiological organisms grow in fuels when separated and or entrained water is present. They will not grow in a water-free environment. The microbiological organisms start to form at the fuel-water interface and subsequently develop strands/fibers and/or "mats" into the fuel or produce a slime on the interior surfaces of the tank. Moderate to warm ambient temperatures will accelerate the growth and proliferation of these micro-organisms.

ll. **Will microbiological organisms grow in both JET A-1 and diesel fuels?**

Answer: **Yes**. Microbiological organisms will however grow more rapidly in diesel fuel than JET A-1 as (1) diesel fuel tends to entrain more water than JET A-1 and has poorer water separation qualities, and (2) diesel fuel contains higher amounts of normal paraffin-type hydrocarbons than JET A-1 which are more favored as a nutrient by the various micro-organisms.

mm. **What additives should be used for controlling microbiological growth (i.e., bugs) in fuel?**

Answer: There are two (2) additives currently in the supply system which prevent/control the formation of microbiological growth in water bottoms of fuel tanks/cell. One of the additives is currently specified in JP-4/JP-5/JP-8 aviation turbine fuels whereas the other is recommended for use in diesel fuel as a means to enhance its storage stability and control of micro-organisms.

The additive for aviation turbine fuel is called "Fuel System Icing Inhibitor" and is described by MIL-DTL-85470. The chemical ingredient is Diethylene Glycol Monomethyl Ether (DIEGME). The recommended treatment level in either turbine or diesel fuel is 0.10 to 0.15 vol %.

The other additive for diesel fuel is called the Diesel Fuel Stabilizer Additive and is described by MIL-S-53021. There are two types of stabilizer additive that have been qualified, a two-package and one-package system. In the two-package type, the biocide is in one package or container, and the remaining multifunctional stabilizer/corrosion inhibitor additive, is in the other. Both of them must be ordered and used together for maximum effectiveness. Both are used at the rate of one gallon per 5000 gallons of fuel. The one-package type stabilizer additive however has both ingredients blended together in one container. It is used at the rate of one gallon of additive per 3500 gallons of fuel.

nn. **Do micro-organisms (i.e., bugs, bacteria, fungus, etc.) grow in JP-8?**

Answer: **No**. Microbiological growth will not occur in JP-8 fuel as this fuel contains the Fuel System Icing Inhibitor (FSII) which also reduces the tendency of micro-organisms to exist in fuel tanks. Without the FSII being present, microorganisms will grow if water contamination exists in the fuel tank environment.

pp. **What is a "biocide"?**

Answer: A biocide is a chemical compound which when added to a liquid or petroleum fuel functions as a sterilizing agent; i.e., it will kill all micro-organisms present. The proper application of a biocide to a system for which that biocide has efficacy (i.e., produces its intended effect) will kill all susceptible microorganisms in the system. An example of a biocide available in the military supply system is the MIL-S-53021 Diesel Fuel Stabilizer.

pp. **What is a "biostat"?**

Answer: A biostat is not, in the strictest sense, a sterilizing agent. Although used in the same manner as a biocide, the presence of a biostat in a system will retard the growth of micro-organisms in the system. However, viable organisms may still be present in the system. In some instances, a biostat can partition to the water phase in a fuel/water system in large enough concentration to effectively become a biocide. An example of a biostat compound which is available in the military supply system is MIL-DTL-85470 Fuel System Icing Inhibitor.

qq. **Do you have to change fuel filters on vehicles/equipment previously serviced with diesel fuel when using JP-8 or JP-5?**

Answer: **No**. No requirement exists for changing fuel filters on those vehicles/equipment that have been routinely exercised and properly maintained. For those vehicles/equipment that have been under some extended period of inactivity and there is some suspicion that maintenance may not have been as complete as desired, changing of fuel filter elements should be considered as an insurance measure.

rr. **Are there any special requirements for servicing tank truck refuelers previously containing diesel fuel prior to their being filled with JP-8 or JP-5?**

Answer: See "Recommendations For Diesel Fuel to JP-8 Conversion", pages 32-34.

ss. **If JP-8 or JP-5 are introduced into vehicles/equipment previously serviced with diesel fuel, will there be any problems?**

Answer: **No**. With vehicles/equipment that have been routinely exercised, been properly maintained, etc., there will be no problems. However, for vehicles/equipment that have been somewhat inactive or those which have not had proper maintenance pulled such as routinely removal of water/debris from fuel cell/tank sumps, etc., introducing JP-5 or JP-8 to those vehicles/equipment could cause a slight increase in replacements of fuel filters. This would be due to the presence of the Fuel System Icing Inhibitor in JP-8/JP-5 which will (1) gradually kill microbiological organisms (i.e., bugs) present in fuel tanks where water bottoms exist and cause this "dead" microbiological debris to be carried into the fuel filter and/or, (2) slowly dissolve some the deterioration products left by previous diesel fuel service (i.e., gums, sediment) and cause this "dissolved contamination" also to be carried into the fuel filter.

FACT SHEET ON

ENERGY CONTENT OF

GROUND FUELS

<u>FACT SHEET</u>

SUBJECT: Energy Content of Ground Fuels

PURPOSE: To provide a clarification regarding JP-8 and its impact on fuel consumption

<u>FACTS</u>

1. Fuel properties that affect diesel engine performance are energy content, ignition quality, viscosity, and volatility.

2. The power output of an engine is governed by the energy content of the fuel and the combustion process that releases this energy.

3. Energy content per unit volume (i.e., Btu/gal) usually increases as the specific gravity increases or as the API gravity decreases. This change in energy content generally translates into an increase or decrease in fuel consumption.

4. Much concern has been raised in the Single Fuel on the Battlefield initiative regarding the increased fuel consumption anticipated with use of JP-8 in lieu of diesel fuel. This anticipated increased fuel consumption is expected to translate to a decrease in vehicle range.

5. It has been tentatively stated that in conversion from diesel fuel to JP-8, one can anticipate a nominal five (5) percent increase in fuel consumption or decrease in vehicle range.

6. This five (5) percent is derived from the energy content per unit volume difference between JP-8 and diesel fuel. Recently-conducted limited testing at Fort Bliss, TX, to determine actual vehicle consumption rates have shown this "calculated projected fuel consumption increase" to represent the worst case as some of the determined fuel consumption values were <u>less</u> <u>than</u> the five (5) percent projection.

7. To provide additional information on this matter, the energy content per unit volume (Btu/gal) values were determined for the four classes of fuels involved; namely —

   - CID A-A-52557 LS DF-2. This represents the diesel fuel used in CONUS and reflect that fuel used by engine manufacturers in qualification and testing of engine systems.

   - CID A-A-52557 LS DF-2 (OCONUS). This is the diesel fuel which is interchanged within NATO under Code No. F-54. This fuel is used in NATO.

   - F-65. This is the 50:50 mixture of F-54 with either JP-8 or JP-5 fuel that was instituted in the 1981-82 winter by the U.S. because of cold weather waxing problem. Prior to the establishing of a Code No., it was called the "M-1 Fuel Mix".

   - JP-8. This is the kerosene base turbine fuel which is interchanged within NATO under Code No. F-34.

8. The calculated net or lower heat of combustion (Btu/gal) for the four classes of fuels based upon nominal values are as follows:

Property	LS DF-2	F-54	F-65	JP-8 (F-54)
Density @ 15°C	0.8524	0.8330	0.8162	0.7995
Gravity, °API	34.5	38.3	41.9	45.4
Net Heat of Combustion	130,819	127,716	125,457	123,138
% Less Btu/gal than DF-2	0	-2.0	-3.7	-5.5

9. Although these reflect averaged values which will deviate to some degree based upon subtle differences in composition, it is significant to note that use of F-65 since 1981-1982 during the periods November through April annually has "theoretically" resulted in a net 4% increase in fuel consumption which, if real, should have caused an increase in the fuel requirements for ground forces operating in Europe.

10. To the best of our knowledge, no change in fuel requirements have occurred to date for the NATO theater as a result of this annual change from F-54 to F-65. Moreover, SB 710-2 (Combat Consumption Rates for Ground and Aviation POL) gives vehicle/equipment fuel consumption rates which are based upon a reference DF-2 and not F-54.

Tank-Automotive RDE Center
ATTN: AMSTA-TR-D/210
September 2000

FACT SHEET ON

CONVERSION TO JP-8

FACT SHEET

SUBJECT: Conversion to JP-8 Fuel

PURPOSE: To provide brief historical chronology and status regarding subject conversion

FACTS:

- Conversion within NATO from JP-4 to JP-8 for aircraft initially proposed in 1976; rationale being commercial availability, increased safety, and improved interoperability.

- Conversion process delayed during late 1970s because of requirement for cold startability of helicopters, and projected increased price differential.

- Introduction of Abrams Main Battle Tank (M1) into Germany in late 1981 along with other gas turbine powered equipment surfaced severe cold startability problems with NATO standard diesel, F-54; interim fix involved blending with either JP-5 or JP-8 to lower cloud point of diesel fuel.

- Policy subsequently adopted by U.S. Army in Germany was to blend <u>all</u> F-54 with either JP-8 or JP-5 prior to diesel fuel exiting Class III fuel supply points.

- Blended fuel, referred to as "M1 Fuel Mix", has since been used by all diesel-fueled equipment in forward areas during November through April annually. Other NATO countries subsequently adopted this mixture (i.e., 50% F-54 and 50% JP-8 or JP-5) now interchanged as F-65.

- NATO countries experiencing similar low temperature operability problems.

- At February 1986 FAA on Armor, Issue A-D-2 surfaced M1 cold starting problem. Use of JP-8, subsequently recommended as a fix was concurred on by GEN Thurmond.

- Message from HQDA to AMC on 25 February 1986 requested position on JP-8 as alternate to diesel fuel. Coordinated response on 14 March 1986 confirmed acceptability of JP-8 by all major subordinate commands.

- NATO Ministers agreed to convert from F-40 (JP-4) to F-34 (JP-8) with agreement ratified on 1 January 1987.

- AR 703-1 published 5 January 1987 listed JP-8 as well as JP-5 alternates for diesel-fueled equipment.

- Following coordination within the military services, DoD Directive 4140.43 on Fuel Standardization was issued 11 March 1988 specifying primary fuel support for air-land forces being JP-8.

- Within NATO, a draft STANAG 4362 entitled "Fuel Requirements In Future Ground Equipment" was developed in October 1987 and is now being coordinated. The draft STANAG parallels DoD Directive 4140.43.

- At February 1988 FAA on Armor, Issue 17-102-A surfaced non-smoke characteristics of JP-8 when used in M1's Vehicle Engine Exhaust Smoke System (VEESS).

- Message from HQDA on 14 April 1988 acknowledging non-smoke VEESS issue with JP-8 tasked PEO Chemical/Nuclear to lead in resolving the problem.

- Action Officers held 28 April 1988 with agreement reached to develop plan for installing under-armor form-fitting tank. Completion date of FY 1991 was tentatively established for retrofit of M1/M1A1, M2/M3, and M60A3 vehicles. Unfunded "Retrofit VEESS Plan" forwarded to HQDA in July 1988.

- Limited testing of M88A1, M1A1, M113A2, M1009, and M928 vehicles at Ft. Bliss completed assessing fuel consumption, acceleration times, and not starting limitations with JP-8 Average increase in fuel consumption for all test vehicles was 3.9%.

- Proposal for conducting a JP-8 Demonstration with diesel fueled vehicles/equipment sent from HQ AMC on 27 July 1988 to both TRADOC and FORSCOM; Ft. Bliss, TX, being preferred site.

- Coordination meeting held 10 August 1988 at CRDEC to develop unified approach for JP-8 Non-smoke VEESS problem; Retrofit VEESS Plan represented only solution attainable in the near term (FY 1991).

- In response to AMC's requesting the JP-8 Demonstration, both TRADOC and FORSCOM concurred and identified Ft. Bliss as the site. An initial planning held on 28 September 1988.

- Follow-on meeting for JP-8 Demonstration on 29 November 1988 wherein program plan was finalized.

- At 15 December 1988 briefing to TRADOC, MG Maddox non-concurred with Retrofit VEESS Plan citing unacceptable logistical burden. MG Maddox requested three proposed technology base solutions (i.e., flash distillation, thermomechanical fixes, and additives) be actively pursued.

- NATO's Central Europe Operating Agency completed conversion from JP-4 (F-40) to JP-8 (F-34) within Central Europe Pipeline System (CEPS) on 18 August 1988. Other NATO Pipeline Systems being converted.

- U.S. Conversion from JP-4 to JP-8 for land-based aircraft within NATO completed October 1989.

- U.S. conversion from diesel fuel to JP-8 for ground vehicles/equipment within NATO scheduled fully implemented by FY 1992.

- In August 1990, DoD implemented Single Fuel on the Battlefield by providing JET A-1 (i.e., JP-8 without its three mandatory additives) for U.S. Forces in Operation Desert Shield.

- Because of reported user concerns (i.e., lack of VEESS capability, fuel pump problems, etc.), ARCENT/CENTCOM agreed in December 1990 commanders have fuel of choice in theater; some divisions using host nation diesel fuel whereas others use JET A-1 for ground materiel.

- In May 1991, Vice Chief of Staff requests AMC and TRADOC relook the Retrofit VEESS Plan and other quick mechanical retrofit approaches instead of considering possible conversion back to diesel fuel.

- In May 1991, Joint Working Group on Interim Fix to VEESS recommended Army immediately resource development and acquisition of Under Armor Fog Oil Tank for VEESS modification to restore VEESS capability.

- JP-8 Demonstration Program at Ft. Bliss, TX, officially ended 30 September 1991.

- In October 1991, Ft. Bliss given approval to continue indefinite use of JP-8 in lieu of diesel fuel.

- In October 1991, Ft. Hood, TX, given approval to convert from diesel fuel to JP-8.

- U.S. Air Force will initiate conversion from JP-4 to JP-8 at all bases in continental U.S., starting with West Coast locations in 1993.

SUMMARY REPORT

ON

JP-8 DEMONSTRATION FOR

GROUND VEHICLES

JP-8 DEMONSTRATION PROGRAM SUMMARY

The JP-8 Demonstration Program, intended to fully confirm usability of JP-8 for continuous operation in all diesel fuel consuming vehicles and equipment, was initiated at Ft. Bliss, TX, in October-November 1988 with the initial shipments of JP-8 arriving on 31 January 1989. Within the scope of this Demonstration Program, JP-8 was substituted for diesel fuel with on-site personnel monitoring any unresolved operation/compatibility problems, changes in repair/replacement rates of fuel-wetted parts, changes in averaged fuel consumption, changes in engine oil drain intervals, projected maintenance savings, and need for user/operator manuals for changeover from diesel fuel to JP-8.

A total of some 2857 diesel fuel-consuming vehicles and equipment have satisfactorily operated on JP-8. The fuel transition period (that is, the interval during which vehicles and equipment were consuming a mixture of diesel fuel and JP-8) was initially projected to be only one-to-two months in duration. However, due to relatively large quantities of diesel fuel that were on-hand at the Demonstration Program's start in January 1989 and combined with the delayed number of vehicles and equipment exercises and their general operation, this fuel transition period extended to the end of September 1989. From October 1989, all diesel fuel-consuming vehicles and equipment consumed only JP-8.

Summary findings realized were:

- No catastrophic failures have occurred with using JP-8.
- No insurmountable JP-8 related concerns have surfaced; that is, no mission or safety related matters.
- User perception and wide spread acceptance of JP-8 at Ft. Bliss has been favorable.
- No significant differences in vehicles/equipment fuel consumption rates been noted.
- Several major training exercises took place and no JP-8 fuel-related problems have surfaced.
- Army Oil Analysis Program (AOAP) used oil analyses have shown that recommended oil change intervals have been increased somewhat.
- Satisfactory performance realized promoted Ft. Bliss to permanently convert to JP-8 as its standard ground fuel.

These above findings provided further evidence and support for using JP-8 in ground vehicle and equipment systems. One additional noteworthy point is that addressing safety. Comments had surfaced relative to a perceived concern as to possible safety hazards due to the slightly lower flash point of JP-8 versus diesel fuel. Operating and fueling vehicles and equipment with JP-8 at Ft. Bliss which enjoys a relatively hot summer generated no fuel-related safety problems. Moreover, two training exercises were held at the National Training Center at Ft. Irwin, CA, which subjects vehicles/equipment and operations to ambient temperatures higher than normally encountered at Ft. Bliss, TX. Again, during these joint exercises, no safety-related problems occurred.

The recent mobilization for Operational Desert Shield/Storm in July-August 1990 reduced the total vehicle/equipment assets within the JP-8 Demonstration from the 2800 plus items to some 750 plus items due to transfer of elements within the 3rd ACR and the 11 ADA Bde. The formal JP-8 Demonstration has officially ended as of 1 October 1991. Its success had led to the conversion of Ft. Hood, TX, from diesel fuel to JP-8 which was started in late FY 1991.

Interim and final reports covering this JP-8 Demonstration are listed in the Compendium section in pages 104, 114, and 121.

RECOMMENDATIONS FOR DIESEL FUEL TO JP-8 CONVERSIONS

PROPOSED RECOMMENDATIONS FOR TRANSITIONING JP-8 (F-34) FUEL INTO U.S. ARMY GROUND DIESEL FUEL-CONSUMING VEHICLE MID EQUIPMENT MATERIEL

FACTS:

- All JP-8 POL equipment and procedures for non-aviation use should be operated as if required for aviation turbine fuels. Refueler/tankers should be considered ready at all times for refueler/tankers/dispensing equipment that would be suitable for use with aviation equipment. Any mindset that believes JP-8 intended for ground equipment could be handled as though it were diesel fuel would be contrary to the Single-Fuel-Forward concept. The JP-8 to be used in ground equipment must be handled as if it were to be used in aviation equipment.

- Diesel fuels utilized in NATO are, in general, higher quality fuels than typically supplied CONUS diesel fuel and have caused fewer problems in Army mobility ground equipment operated within NATO environment.

- Both JP-8 and diesel fuel mix instantaneously as they are both petroleum refined products.

- JP-8 is a cleaner burning fuel and is considerably more stable than diesel fuel. Operational and maintenance personnel have noted these qualities as well as adding that JP-8 smells better than diesel fuel.

RECOMMENDATIONS:

- Change filter separator elements on all fuel-dispensing equipment previously used for diesel fuel; also change fuel-dispensing pump final filters at above or below ground fuel storage areas that were used with diesel fuel.

- Clean all vehicle refuels/tankers, change filter separator elements, and ensure that these separator elements are in place and in use for all dispensing operations.

- Draw down front and rear fuel cells of all Abrams series tank vehicles.

- Change vehicle and equipment fuel filters only in accordance with established maintenance schedules; more frequent filter changes should be made only if filter plugging occurs. If vehicles and equipment have not been exposed to routine exercising or have consumed relatively low levels of fuel over the past several months, fuel filters should be changed.

- **Older** V/E having had a lengthy period of operation with CONUS diesel fuel would be more prone to fuel system problems.

- Be prepared to field questions/complaints about JP-8 related problems that in **most cases** will be related to **normal** maintenance/fuel-related concerns.

- Draining/cleaning of all motor pool storage tanks and individual vehicle/equipment fuel cells is generally not recommended as this is beyond consideration due to costs, manpower, etc.

- If storage tank (i.e., bulk or intermediate) locations have been experiencing problems related to presence of microorganisms, sterilization of these tanks is recommended by injection of approved biocides provided under MIL-S-53021 as introducing JP-8 may not kill all microbiological growth. (NOTE: procedures for sterilization can be provided upon request).

- For conversion of collapsible tanks previously exposed to diesel fuel, collapsible tanks should first be checked for possible leaks after replacement with JP-8. The first few fuel batches should be tested for contamination by diesel fuel and solid contaminants. Testing should include water separation index and particulates. All fuel discharged from these collapsible tanks should be passed through a filter separator. If filter separators had previously been used for diesel fuel, new filter elements must be installed.

- No special modifications to current fuel-handling equipment is required.

RECOMMENDATIONS FOR JP-4 TO JP-8 CONVERSIONS AND INTERMIXING OF FUELS

CONVERSION FROM JP-4 TO JP-8 AND INTERMIXING OF ALTERNATIVE AIRCRAFT TURBINE ENGINE FUELS [1]

USAF has two primary turbine fuels (JP-4 and JP-8) that are used in all current inventory aircraft. In addition, USAF authorizes the use of several alternate fuels such as JP-5, which has a higher flash point for use on Navy aircraft carriers for safety reasons, and commercial versions of the military fuels which may or may not contain the three (3) additives required in JP-4, JP-5 and JP-8. Three mandatory additives used in all USAF fuel are corrosion inhibitor, fuel system icing inhibitor, and fuel anti-static (or static dissipator) additive. The primary reasons for USAF using the three additives are as follows: (1) corrosion inhibitor increases the lubricity of the fuel as a means of extending aircraft engine, auxiliary power unit (APU), and jet fuel starter (JFS) component life; (2) icing inhibitor prevents the formation of ice from any "free water" in the fuel system/engine; and (3) anti-static additive reduces the probability of static generated vapor ignition in all phases of the fuel transportation, handling, and storage, as well as in the aircraft fuel tanks.

Commercial airlines use turbine fuels which are essentially identical to USAF fuels when treated with the appropriate additives. The terminology used for these fuel include JET B (JP-4), JET A-1 (JP-8), and JET A.

No noticeable performance degradation should be experienced with the use of these alternate fuels. Modern aircraft turbine engines such as those used in current generation aircraft may experience minor degradation in operational characteristics when using alternate fuels (including JP-8). The principle areas affected include air and ground starting, afterburner operation, smoke/afterburner light-off and sequencing may be impacted. Exhaust smoke and afterburner cancellation signature (vapor puff) may increase with alternate fuels. Many of these characteristics further degrade at low temperatures due to higher fuel viscosity. Recent modern turbine engine durability tests have been performed using alternate fuels with the additives with no detectable hardware degradation. Analysis indicates very minor life degradation due to increase afterburner liner/exhaust nozzle temperature. No performance or operability degradation of auxiliary power units should be experienced with alternate fuels at the anticipated operating temperatures.

Conversion from JP-4 to JET A-1, JP-8, or JP-5 fuel may increase aircraft maintenance and degrade system safety due to increased fuel leaks. This is due to the high swell properties of JP-4 and the "permanent set" taken by these seals (especially fluorosilicone) after prolonged periods of operation with JP-4 fuel. Those aircraft deployed from CONUS are most likely to experience fuel leakage. The introduction of (conversion to) JET A-1, JP-8, or JP-5 which have low swell properties will result in seal/sealant shrinkage and the leakage of seals which have taken a "permanent set". These problems are further aggravated by transition from high ambient ground temperatures to low flight temperatures. These fuel leaks may occur anywhere in the fuel system, engine, JFS, or APU. Fuel leakage problems can usually be resolved by the tightening of variable cavity threaded (Wiggins type) fuel couplings, replacement of "O" rings, or the reinjection of fuel tank sealants.

The mixing of high/low volatility fuels has always been a safety concern. This is due to the fact that the two fuels have radically different flammability ranges and when mixed or during mixing operations the flammability characteristics of the mixture can vary from one extreme case to the

[1] This information has been abstracted from a Headquarters U.S. Air Force Aeronautical Systems Division letter dated 25 September 1990, subject: Desert Shield Fuel Issues.

other. As an example, JP-4 is normally flammable throughout the range of -20°F to +60°F and JP-8 is normally flammable throughout the range of +80°F to +130°F. When two different fuels are mixed (switch loading) in aircraft tanks, the mixture is likely to be flammable at some time during the refueling operation regardless of the temperature. This flammability can be hazardous if electrostatic discharge or other ignition sources are present during the refueling. Experience with the C-130 containing reticulated fuel tanks blue foam has demonstrated a propensity toward an increase in fuel tank ignitions during switch loading from JP-4 to JP-8, or JET A-1 fuels. For this reason, switch loading should wherever possible be minimized. Of particular concern would be the case where over the wing gravity refueling is conducted, and of even greater concern is when a fuel tank contains ESM blue foam. This could result in a flash fire and subsequent injury to the servicing personnel and possible aircraft damage.

EPA's APPROVAL OF JP-8 IN 1995 FOR ON-ROAD VEHICLES

APPROVAL OF JP-8 FOR ON-ROAD VEHICLES

Prior to 1 October 1993, DoD was converting from JP-4 and diesel fuel to JP-8 at various military installations in consonance with the Single Fuel Forward Initiative. However, with the Environmental Protection Agency's Regulation of Fuel and Fuel Additives: Fuel Quality Regulations for Highway Diesel Fuel (Low Sulfur Diesel Fuel Standards — LSDFS) enacted 1 October 1993, use of JP-8 in diesel powered ground vehicles was viewed as a violation. This was because the JP-8 specification allowed the fuel sulfur content to exceed the LSDFS of 0.05 wt. % maximum. The JP-8 specification permits the maximum sulfur to be 0.30 wt. %.

At that time, five (5) CONUS installations had converted from JP-4 and diesel fuel to JP-8. The contracts for these had to subsequently be modified to require that the refiners provide a "low sulfur JP-8" version for compliance with the initial EPA ruling. As there were additional costs associated with these contract modifications as well as a loss in flexibility with the Defense Fuel Supply Points, the planned implementation of the CONUS Army ground fuel conversion was placed on hold.

Recognizing that kerosene fuels do not generate the same levels of exhaust emissions as diesel/distillate fuels, the Army conducted a series of engine dynamometer tests for exhaust emissions using military engines. These emission tests, using an EPA established testing protocol, evaluated JP-8 with its sulfur level adjusted to the maximum sulfur content (i.e., 0.3 wt. %) and compared results to the EPA Reference Diesel Fuel having a 0.035 wt. % sulfur value. An executive summary of this testing is provided as well as the complete report being referenced under the Compendium (see page 131). This executive summary is entitled "Comparison of Diesel Exhaust Emissions Using JP-8 and Low Sulfur Diesel Fuel".

Based upon this data, the Office of the Undersecretary of Defense (Environmental Security) formally requested EPA to concur with unrestricted use of JP-8 by the military for highway applications. After reviewing the data, EPA subsequently responded on 1 May 1995 stating in summary that "...JP-8 is not subject to the Agency's Regulation of Fuels and Fuel Additives for Highway Diesel Fuel" (40 CFR Part 80.29-80.30). The EPA approval was given by Mary T. Smith, Director of Field Operations and Support Division.

Comparison of Diesel Exhaust Emissions Using JP-8 and Low Sulfur Diesel Fuel

Executive Summary

The U.S. Army has adopted the strategy of a "single fuel" for the battlefield that provides distinct military advantages in training for and execution of combat operations. Aviation kerosene fuel, MIL-T-83133C grade JP-8 having a maximum allowable sulfur of 0.30 wt. percent is the "single fuel" specified by the Army. However, as of 1 October 1993, the U.S. Environmental Protection Agency (EPA) - regulations mandate a maximum allowable sulfur level of 0.05 wt. percent in diesel fuel for on-highway use, which has effectively denied Army use of JP-8 on the highways. Since the Army believed that kerosene-based fuels such as JP-8 are likely to produce lower diesel exhaust emissions (especially particulate matter) than typical distillate fuel emissions, i.e., from diesel fuel grade 2, an experimental program was conducted by the Army to verify this belief.

Comparative emission measurements were made in two dynamometer-based diesel engines using protocol specified by the EPA and the California Air Resources Board (CARB). A single JP-8 fuel with a sulfur level of 0.06 wt. percent was adjusted to sulfur levels of 0.11 and 0.26 wt. percent and the emission characteristics of the three fuels were compared with the 1994 EPA certification low sulfur diesel fuel (sulfur level equal to 0.035 wt. percent) in the Detroit Diesel Corporation (DDC) 1991 prototype Series 60 diesel engine and in the General Motors (GM) 6.2L diesel engine. Comparisons were made using the hot-start transient portion of the heavy-duty diesel engine Federal Test Procedure. The DDC 1991 Series 60 engine is specified in the EPA and CARB protocol and the GM 6.2L engine is typical of the engine used in the Army's family of aver 100,000 light-duty tactical and commercial wheeled vehicles. The intent of the fuel-emission comparisons was to show that the three JP-8 fuels would have essentially no effect on the gaseous emissions (unburned hydrocarbons, carbon monoxide, and oxides of nitrogen), but would show decreases in particulate matter compared with the EPA reference fuel. The goal of the study is consistent with the fact that the EPA considers the impact of sulfur content in diesel fuel to alter engine particulate matter emissions and considers fuel sulfur to have no effect on gaseous emission response.

Results from the Army study show that the gaseous emissions for the DDC Series 60 engine using kerosene-based JP-8 fuel are essentially equal to values obtained with the 0.035 wt. percent sulfur EPA certification diesel fuel, and that an approximate sulfur level of 0.21 wt. percent in kerosene-type JP-8 fuel would be equivalent to the 0.035 wt. percent sulfur reference fuel. Similarly, the gaseous emissions for the GM 6.2L engine using JP-8 fuel are essentially equal to the values obtained with the 0.035 wt. percent sulfur EPA reference fuel, and all sulfur levels of kerosene-type JP-8 fuel up to the 0.30 wt. percent MIL-T-83133 specification maximum would be equivalent to a 0.035 wt. percent sulfur EPA reference fuel.

While the military's kerosene-based JP-8 specification allows for sulfur levels up to 0.30 wt. percent, the actual sulfur level of 93 samples obtained in an Army survey was 0.07 wt. percent. and the JP-8 sulfur averaged 0.03 wt. percent at Ft. Bliss, TX, during the 21-month period (October 1989 - June 1991). A recent Defense Fuel Supply Center survey of 182 JP-8 fuels delivered to military installations within the continental United States indicated the average JP-8 sulfur level to be 0.035 wt. percent. When one considers the results of the Army engine-fuel emissions study coupled with the reality of actual JP-8 sulfur levels, it is reasonable to conclude that Army use of JP-8 on highway applications will have no effect on diesel gaseous emissions, but will be expected to lower exhaust particulate matter in the diesel-powered fleet.

Comparison of Diesel Exhaust Emissions Using JP-8 and Low Sulfur Diesel Fuel

Introduction

The U.S. Army use of MIL-T-83133C grade JP-8 as the Single Battlefield Fuel was thought to have a potential benefit of being a mare environmentally friendly fuel than diesel fuel. Kerosene-based JP-8 consists of lower molecular weight hydrocarbons, lower end boiling point, and, until recently, lower fuel sulfur content than typical distillate-based diesel fuels. These factors lead to reduced particulate and smoke emissions from diesel engines, and was the primary reason aviation kerosene-based fuel was chosen by urban transit companies for inner city routes.

The MIL-T-83133C specification for grade JP-8 allows a fuel sulfur maximum of 0.30 wt. percent. A worldwide survey of 93 kerosene fuel samples revealed an average sulfur of 0.07-wt. percent. During the JP-8 demonstration program at Ft. Bliss, TX, the average delivered JP-8 fuel sulfur was 0.03-wt. percent over the 21-month period from October 1989 - June 1991. A recent Defense Fuel Supply Center survey of 182 JP-8 fuels delivered to military installations within the continental United States indicated the average JP-8 sulfur level to be 0.035 wt. percent. With the advent of the 1 October 1993 Environmental Protection Agency (EPA) regulation requiring on-highway diesel fuel sulfur to have a maximum of 0.05-wt. percent sulfur, the refiners of JP-8 have been unwilling to guarantee that deliveries of JP-8 will always meet the EPA low sulfur fuel requirement.

The EPA specification of 0.05-wt. percent maximum sulfur resulted from data generated with full boiling range diesel fuels. The specification level for diesel fuels was determined to be that required for diesel engines to meet the proposed 1994 heavy-duty diesel engine particulate emission requirements. However, the differing chemical and physical properties of kerosene and diesel fuel raises the question of the effect of the fuel hydrocarbon type with respect to fuel-sulfur level on diesel engine exhaust emissions. A review of available literature revealed that the effects of fuel sulfur on kerosene exhaust emissions had not been previously investigated. The intent of the Army study was to evaluate these effects in a Detroit Diesel Corporation (DDC) 1991 prototype Series 60 diesel engine, a recognized fuel certification engine; and an engine representing a large portion of the Army's wheeled vehicle fleet, a General Motors (GM) 6.2L diesel engine.

Background

The current EPA and California Air Resources Board (CARB) specified fuel formulations are based in part on landmark research funded by the Coordinating Research Council. The 1989-1990 study evaluated diesel fuel properties effects on exhaust emissions in a prototype 1991 DDC Series 60 engine with respect to 1991 emission levels. The study resulted in EPA regulating diesel fuel to 0.05-wt. percent maximum sulfur for 1994, and CARB regulating diesel fuel to 0.05-wt. percent maximum sulfur, 10-vol. percent maximum aromatics, and 48 minimum cetane number for 1994. For both the CARB and EPA fuels, the 0.05-percent sulfur level is invariant; however, CARB allows refiners who sell fuel in California to vary aromatics and cetane number to prove a substantially similar fuel to the 1994 CARB reference fuel. Currently, EPA allows CARB to define a substantially similar fuel to 1994 diesel fuel formulation by comparing the emission results of a CARB referee fuel with the candidate fuel recipe in a prototype 1991 DDC Series 60 engine. The candidate fuel recipe is considered substantially similar by definition if it produces the equivalent or lower regulated emissions as the 1994 reference fuel and does not exceed the 1991 exhaust emission levels in the prototype 1991 DDC Series 60 engine hardware.

In comparing the results of the emission performance evaluations of the various sulfur level JP-8s with respect to the 1994 EPA low sulfur diesel reference fuel, it is important to use the prototype 1991 DDC Series 60 engine hardware. EPA utilized 1991 hardware to define the sulfur level for the 1994 low sulfur diesel reference fuel, which by EPA definition is the sulfur level fuel required to meet 1994 particulate emission requirements in 1994 hardware. Other fuels that realize equivalent or lower particulate emissions than the 1994 low sulfur diesel reference fuel in 1991 hardware should also realize lower emissions in 1994 hardware. A procedure similar to the one EPA permits CARB to implement for certifying 1994 fuels in 1991 hardware was used in the current Army study to generate emissions data for JP-8 with respect to a 1994 EPA low sulfur certification diesel fuel.

Approach

Evaluations were performed on three sulfur levels of JP-8 and compared to an EPA diesel certification fuel in an SwRI DDC 1991 prototype Series 60 engine and an Army GM 6.2L engine utilizing the hot-start transient portion of the heavy-duty diesel engine Federal Test Procedure (FTP). The base JP-8 fuel contained 0.06-wt. percent sulfur, which was subsequently treated to attain 0.11- and 0.26-wt. percent sulfur utilizing di-tertiary butyl disulfide. Di-tertiary butyl disulfide is the additive recognized for adjusting sulfur levels for fuels research. The EPA certification diesel fuel utilized as the reference fuel for these evaluations contained 0.035-wt. percent sulfur. The sulfur specification range for EPA certification fuels is 0.03-0.05-wt. percent. The tests were performed utilizing the command cycle as determined using diesel fuel for all fuels evaluated. This procedure ensured that all partial load points were performed at consistent brake mean effective pressures, regardless of fuel type, which is the usual occurrence when fuel types are switched in an engine. The operator extracts the work required from an engine to perform a mission, regardless of the engine fuel rack setting.

Results

The apparent single objection EPA has for allowing the Army to consume JP-8 in their tactical wheeled vehicles is the inability to guarantee the JP-8 pool will always meet the 0.05-wt. percent maximum sulfur specification for on-highway diesel fuels. The predication for the EPA objection is the sole effect of increased sulfur in fuels is to increase particulate matter emissions.

The results for the hot-start transient regulated emissions for unburned hydrocarbons, carbon monoxide, oxides of nitrogen, and particulate matter are shown in **TABLE 1** for 1991 prototype Series 60 engine. The unburned hydrocarbon emissions for all sulfur levels of the JP-8 fuels are slightly higher than the reference 0.035-wt. percent sulfur EPA certification fuel. The carbon monoxide emissions for all JP-8 fuels are lower, and with the exception of the 0.06-wt. percent sulfur JP-8, the oxides of nitrogen response are lower than the EPA certification fuel. The particulate matter emission data indicate the 0.06- and 0.11 -wt. percent sulfur JP-8 fuels have lower particulate emissions even though bath fuels exceed the 0.05-wt. percent sulfur EPA requires for on-highway fuels. Based on a linear interpolation of the particulate matter data shown in **Figure 1**, the equivalent sulfur level JP-8 for the 1991 Prototype DDC Series 60 engine, to achieve the corresponding particulate matter emission level as the reference EPA certification diesel fuel, is approximately 0.21-wt. percent sulfur.

TABLE 1. Prototype 1991 DDC Series 60 Hot Start Transient Emission Results, grams/bhp-hr

Fuel	UHC	CO	NOx	PM
0.035-Percent S DF-2	0.5348	1.9268	4.4131	0.1697
0.06-Percent S JP-8	0.5508	1.6205	4.5048	0.1320
0.11-Percent S JP-8	0.6298	1.6960	4.3653	0.1533
0.26-Percent S JP-8	0.5530	1.5760	4.3630	0.1765

A GM 6.2L engine was purchased from the military supply system since the engine is no longer available commercially. The GM 6.2L engine underwent a 125-hour service accumulation, as specified by the FTP, utilizing a load cycle supplied by General Motors Powertrain. The engine was then installed in a transient emission test cell for the hot start transient emission evaluations. The results for the hot-start transient regulated emissions for unburned hydrocarbons, carbon monoxide, oxides of nitrogen, and particulate matter are shown in **TABLE 2** for the 1990 GM 6.2L engine. The data for the regulated emissions for unburned hydrocarbons, carbon monoxide, and oxides of nitrogen indicated the 1990 GM 6.2L engine had a mixed response with the JP-8 fuels with respect to the reference 0.035-wt. percent sulfur EPA certification fuel. The unburned hydrocarbon and carbon monoxide gaseous emission response for the 0.06-percent sulfur JP-8 was high compared to the other fuels. A lower oxides of nitrogen response for the 0.06-percent JP-8 is consistent with the trend expected for higher unburned hydrocarbon and carbon monoxide response. The two other high sulfur JP-8 fuels revealed lower unburned hydrocarbon, carbon monoxide, and oxides of nitrogen emissions than the reference EPA certification fuel. The GM 6.2L engine revealed lower particulate matter emissions than the reference EPA certification fuel with all JP-8 sulfur levels, even though all JP-8 sulfur levels exceed the low sulfur fuel specification. A linear extrapolation of the particulate matter data shown in **Figure 2** indicate all sulfur levels of IF-B, up to the 0.30-wt. percent MIL-T-83133 specification maximum, would result in lower particulate matter emission levels than the reference EPA certification fuel in the 1990 GM 6.2L engine.

TABLE 2. 1990 GM 6.2L Engine Hot Start Transient Emission Results, grams/bhp-hr

Fuel	UHC	CO	NOx	PM
0.035-Percent S DF-2	0.4540	1.8222	3.2519	0.2905
0.06-Percent S JP-8	0.6398	2.1150	3.2168	0.2288
0.11-Percent S JP-8	0.4363	1.7718	3.2420	0.2283
0.26-Percent S JP-8	0.4115	1.7545	3.2400	0.2715

Summary

The Environmental Protection Agency considers the impact of sulfur content in diesel fuel to alter the particulate matter emissions of an engine and is considered to have no effect on gaseous emission response. The EPA requirement of 0.05-wt. percent maximum sulfur for on-highway diesel fuels is the defined sulfur level for 1994 diesel engines to meet the 1994 particulate emission specification. The comparisons of <u>kerosene</u> fuels with sulfur contents greater than 0.05-percent, in two distinctly different engines utilizing the hot-start transient portion of the Federal Test Procedure for heavy-duty diesel engines has produced the following results:

- A 1991 Prototype Detroit Diesel Corporation Series 60 engine particulate matter response reveals an approximate sulfur level of 0.21-wt. percent in kerosene type JP-8 would be equivalent to a 0.035-wt. percent sulfur EPA certification diesel fuel.

- A 1990 General Motors 6.2L engine particulate matter response reveals that all sulfur levels of kerosene type JP-8. up to the 0.30-wt. percent MIL-T-83133 specification maximum, would be equivalent to a 0.035-wt. percent sulfur EPA certification diesel fuel.

- The gaseous and particulate emission data from the 1991 Prototype DDC Series 60 engine and the 1990 GM 6.2L engine indicate both engines would meet their respective model year gaseous and particulate emission requirements with all sulfur levels of kerosene-type JP-8.

The particulate emission data suggest kerosene-based JP-8 fuels have sufficiently different chemical and physical properties than distillate-based fuels such that the correlation of fuel sulfur with respect to particulate for distillate type fuels cannot be applied directly to kerosene fuels.

U.S. Army TARDEC
Mobility Technology Center-Belvoir
BFLRF (SwRI)
13 October 1994

Figure 1

1991 Prototype DDC Series 60
Hot-Start Transient Emissions

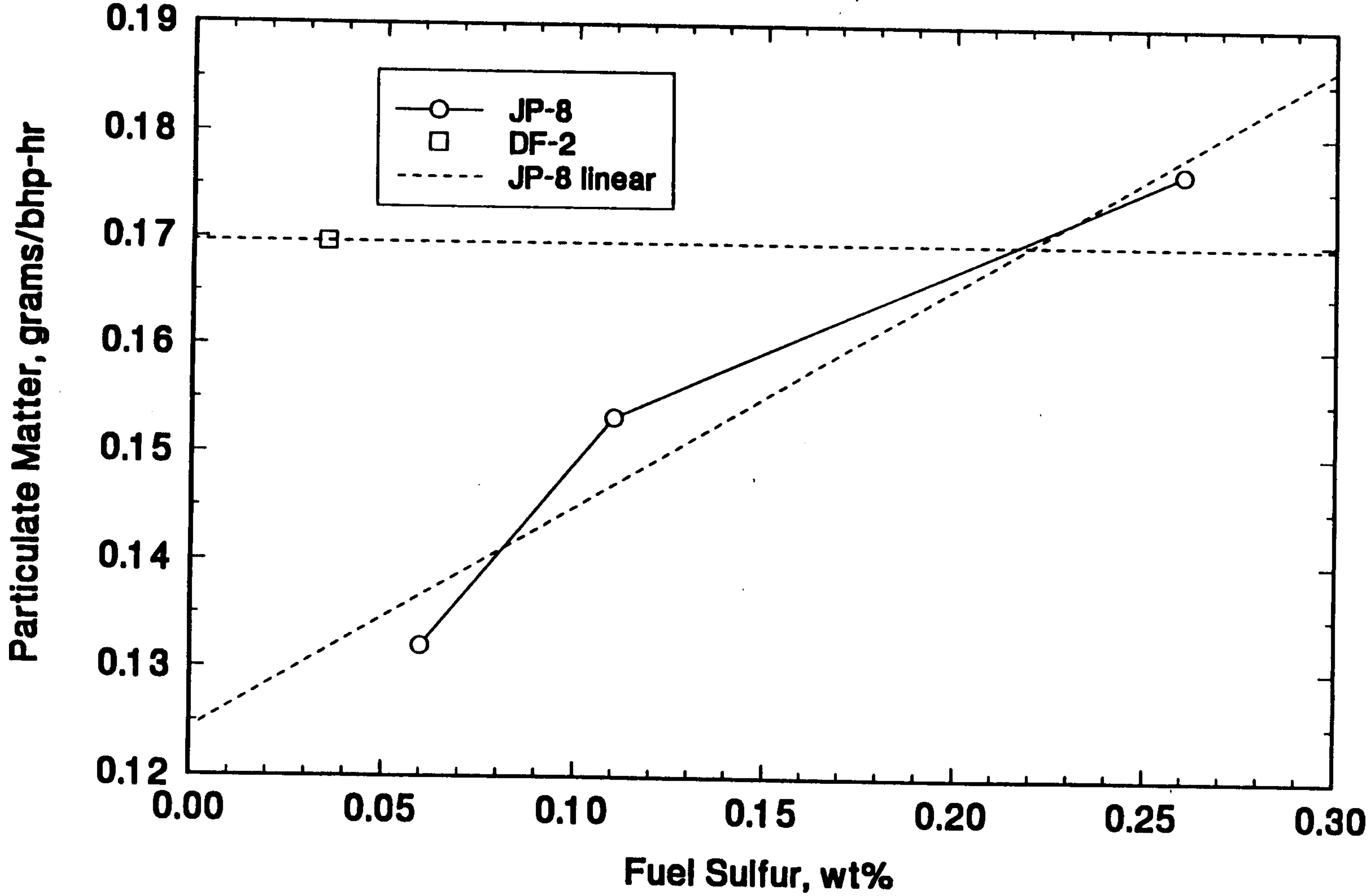
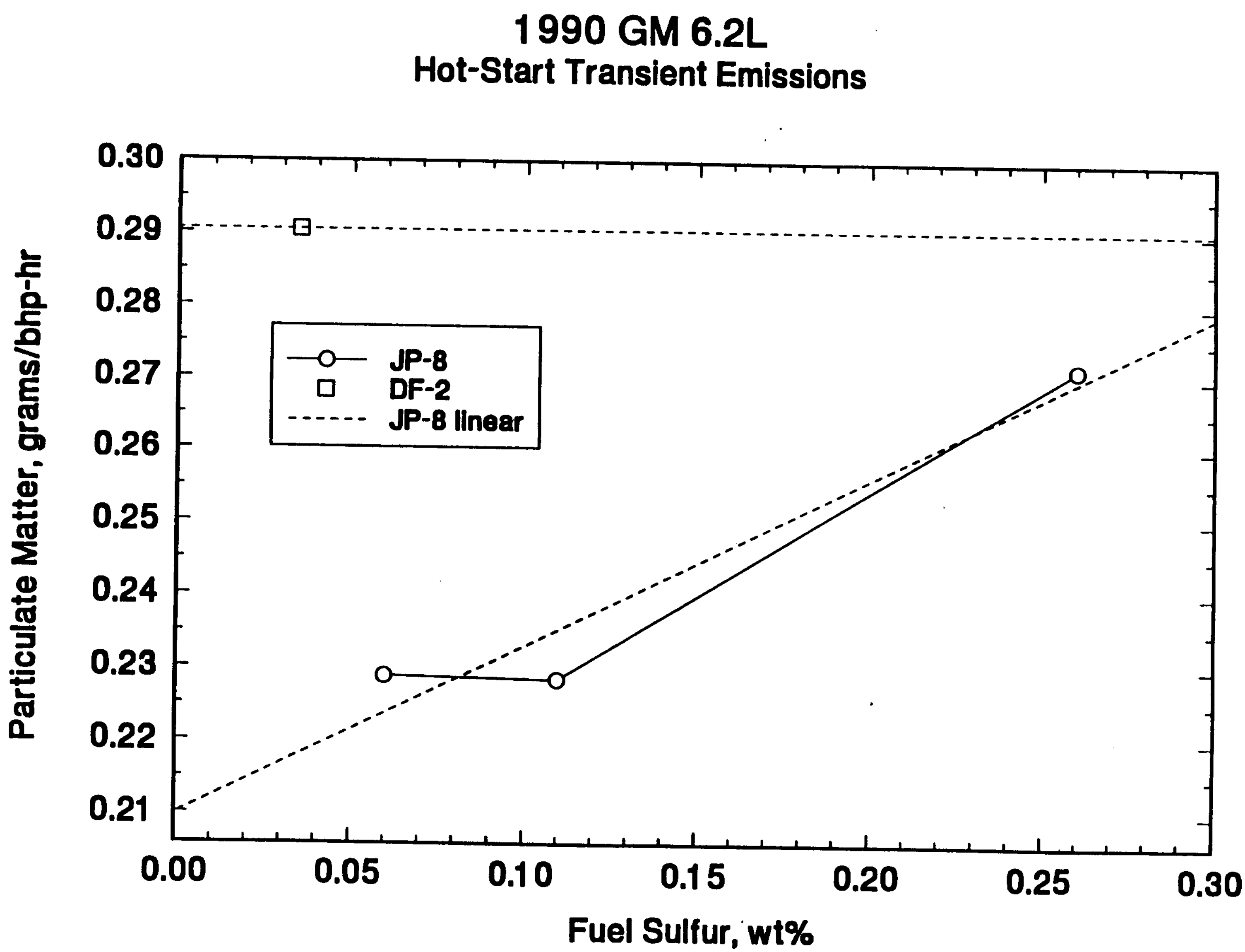


Figure 2


1990 GM 6.2L
Hot-Start Transient Emissions
Particulate Matter, grams/bhp-hr
0.30
0.29
0.28
0.27
0.26
0.25
0.24
0.23
0.22
0.21
JP-8
DF-2
JP-8 linear
0.00
0.05
0.10
0.15
0.20
0.25
0.30
Fuel Sulfur, wt%

FUTURE LEGISLATION IMPACTING USE OF JP-8

FUTURE LEGISLATION IMPACTING USE OF JP-8

Prior to EPA's issuing of their Proposed Ruling dated 2 June 2000 which proposed to limit the allowable sulfur level in 2007 for all on-road diesel fuel to a maximum of 15 parts per million (ppm), EPA provided a draft of this ruling to DoD and requested comments. Their specific interest centered on section VI.D of the Proposed Ruling which was titled "What about the Use of JP-8 Fuel in Diesel Equipped Military Vehicles?"

Section VI.D described the intention of EPA to rescind the exemption/ruling that had been given in 1995. The stated reason being the technical evaluation performed in 1995 was only applicable to vehicle technology at that time and not for the 2007 timeframe. EPA was concerned that even if the exemption is continued for only older vehicles, there would be a risk that 2007 models vehicles could be exposed to the current low sulfur diesel fuel which allows up to 500 ppm. The proposed EPA ruling prompted a meeting between Air Force, Navy, Army, and DESC on May 15, 2000 with a number of action items being identified for each service to provide before a response to EPA could be prepared.

At this time, combat systems are exempt from EPA regulations under the to National Security Exemption which states "Any nonroad engine, otherwise used in a vehicle that exhibits substantial features ordinarily associated with military combat such as armor and/or permanently attached weaponry and which will be owned and/or used by an agency of the federal government with responsibility for national defense, will be considered exempt from these regulations for purposes of national security. No request for exemption is necessary."

The Army's position is that all tactical equipment and or vehicles that do not have permanently attached armor or weaponry must continue to maintain a National Security Exemption based on the direct support role they share with armored/combative vehicles and equipment, and due to the fact that they must also use JP-8 under the Single Fuel for the Battlefield approach.

The EPA proposed rule would regulate heavy-duty vehicle and fuel as a single system. These new emission standards will take effect for applicable 2007 model vehicles and require the new sulfur limits (i.e., a maximum of 15 parts per million) for diesel fuel to be sold beginning June 1, 2006. The Department of Defense (DoD) generated their final comments to EPA which specifically addressed five areas of concern as it relates to the potential impact of the proposed rule on mission readiness. The five areas identified were (1) Lubricity concerns, (2) Potential impact on the availability and quality of specialty fuels, (3) Distribution system impacts, (4) Need to make use of National Security exemption procedures for engine standards; and (5) Use of JP-8 fuel in diesel-equipped military vehicles in the United States. The specific comments were:

Comment: DoD is concerned that the voluntary approach for the maintenance of fuel lubricity has shortcomings from both customer economic and reliability perspectives.

Comment: DoD has concerns regarding the potential impact of the proposed rule on the availability and quality of military fuels, especially the aviation fuels JP-5 and JP-8.

Comment: DoD is concerned that the multi-product commercial pipeline system will be strained to the point that it will be unable to accommodate the transportation of military fuels.

Comment: DoD will need to make use of the existing National Security Exemption procedures to exempt tactical heavy-duty diesel vehicles from engine standards that do not allow use of JP-8, or other diesel fuel used outside of the U.S., because of sulfur intolerant emissions control technology.

Comment: EPA should continue its determination that JP-8 does not meet the definition of diesel fuel under EPA's regulations and that operational readiness, logistical considerations and cost considerations warrant allowing use of JP-8 in military tactical motor vehicles.

For each of the five comments, specific recommendations were given for each to assist in EPA's formulating its final decision. The letter with comments and recommendations was forwarded to EPA on 11 August 2000. It was signed by Sherri W. Goodman, Deputy Under Secretary of Defense (Environmental Security).

RECOMMENDED LUBRICITY GUIDELINES FOR GROUND FUELS

ARMY's RECOMMENDED LUBRICITY REQUIREMENTS

The question of lubricity deficiencies in JP-8 and JP-5 fuels, rumored prior to and during the introduction of the Single Fuel on the Battlefield, surfaced during Operation Desert Shield/Storm when U.S. Forces used ASTM D1655 JET A-1 turbine fuel as a ground vehicle fuel. During and following this conflict, U.S. Army research and development efforts identified oxidative corrosive wear and scuffing to be occurring primarily in fuel-lubricated rotary-type fuel injection pumps with use of low viscosity fuels. This research led to the development of the U.S. Army Scuffing Load Wear Test (SLWT).

Concurrent with this, the mandated introduction of Low Sulfur Diesel Fuel (LSDF) in October 1993 in consonance with EPA's Clean Air Act Amendments further emphasized the need for lubricity controls. The development of an industry standard (i.e., both procedure and limits) for diesel fuel lubricity is currently on-going under the International Standards Organization's Technical Committee 22, Subcommittee 7, Working Group 6 which is commonly referred to as ISO TC22/SC7/WG6; also, ASTM D02.E on diesel, burner and gas turbine fuels, and in the Coordinated European Council (CEC).

Establishing both a lubricity test and its limits has been difficult because of the manner in which wear-related problems occur. The rate of fuel consumption, age/condition of components and engine, ambient temperatures, viscosity of fuel, environmental conditions (i.e., low versus high humidity, sand, dirt, etc.), degree of filtration, engine operating cycle, etc. all factor into the rate at which wear is produced. Additional difficulties have centered on designing the testing cycle needed for correlating the laboratory test with the accelerated pump durability testing.

Using lubricity deficient fuels does not necessarily result in highly visible catastrophic wear as the rate at which it occurs is often unpredictable. In a majority of the situations, wear may not be apparent but is nonetheless occurring at a "non visible rate" and therefore is not discernable to the operator(s). This mode of wear is perhaps the most troublesome as it creates the illusion of acceptability when in reality, long term problems will become a fact of life.

Although the ISO TC22/SC7/WG6 has tentatively identified the High Frequency Reciprocating Rig (HFRR) as the laboratory test method for measuring fuel lubricity, there continues to be growing support in the U.S. for the Army's SLWT. To illustrate this, NAVISTAR International, DETROIT DIESEL Corporation, Engine Manufacturers' Association, The Maintenance Council, and the State of California require/cite the SLWT for assuring fuel lubricity with minimum Scuffing Load values ranging from 2800 grams to 4000 grams. Additionally, CHEVRON Company has reported to be using a 2600 gram minimum limit as an interim lubricity target for their refinery production LSDF. The American Petroleum Institute reportedly issued a warning to member companies regarding possible fuel system failures resulting from using fuels having low lubricity defined as less than 2200 grams Scuffing Load.

Because of the anticipated delay in industry's finalizing the laboratory test and its associated limits when coupled with the uncertainty of wear-related problems and their impact on operational readiness, the Army is recommending "interim lubricity requirements" for both LSDF and JP-8/JP-5 turbine fuels.

For LSDF's **DL-A (Arctic Diesel)**, **DL-1 (Low Sulfur 1-D)**, and **DL-2 (Low Sulfur 2-D)**, and **JP-8/JP-5 Fuels —**

	SLWT, Scuffing Load, grams, min	**HFRR**, Wear Scar Diameter, mm, max, @ 25°C
DL-A	2000	0.54
DL-1	2200	0.51
DL-2	2800	0.38
JP-5	2000	0.54
JP-8	2000	0.54

Use of these **"interim lubricity requirements"** assumes the following conditions/assumptions are met and understood.

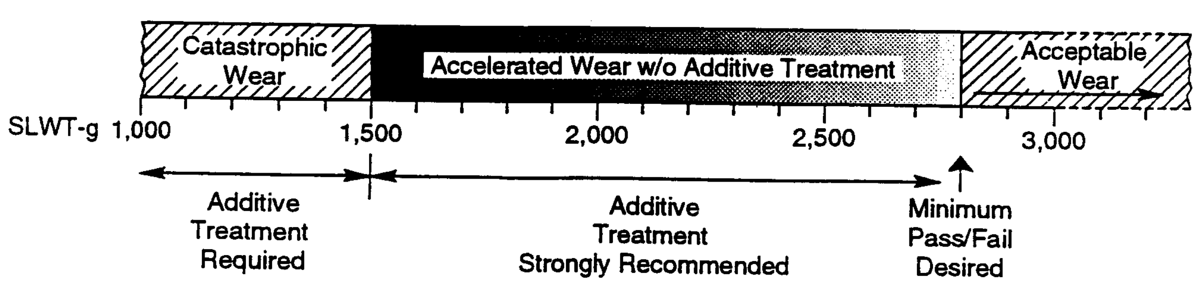
- DL-A and DL-1 will only be used when required because of lower ambient temperatures. That is, using these winter grade fuels continuously during the summer months could generate accelerated wear of fuel-lubricated rotary-type fuel injection pumps.

- Establishing **"interim lubricity requirements"** for the more viscous DL-2 higher than those for the less viscous JP-8/JP-5 and DL-A fuels would on the surface appear to be inconsistent. The rationale for this is twofold; (1) the 2800 gram minimum was based upon early ISO cooperative pump durability testing indicating this level of lubricity needed for insuring operation for at least 100,000 miles without invalidating EPA's engine emissions compliance and, (2) the improbability of any low viscosity fuels having lubricity levels in this range.

- All fuels, regardless of grades, having Scuffing Load values below **2800 grams** will in all probability experience accelerated wear when used in fuel-lubricated rotary injection pumps.

- Fuels having Scuffing Load values below **2800 grams** are strongly recommended to be additive-treated using the MIL-I-25017 Corrosion Inhibitor/Lubricity Enhancer at ten (10) times the specified recommended maximum concentration, or a treatment level of **250 ppm**; fuels having Scuffing Load values below **1500 grams must be additive treated** as stated.

- Expected rotary-type fuel injection pump wear rates and additive treatment requirements for all fuels are illustrated below:



JP-8 and JP-5 have been and are considered acceptable alternate fuels for any of the grades of LSDF. At present, lubricity testing experience with these turbine fuels is less than with diesel fuels. The majority of Scuffing Load values on these JP-5/JP-8 fuels are in the range of **1300 to 2100 grams**. JP-8 and JP-5 are widely used as ground vehicle fuels in Europe and have been used across-the-board in a wide variety of combat, tactical, and administrative-type vehicles and equipment at Fts. Bliss, TX, Hood, TX, and Irwin, CA, for several years with no reports of unusual problems associated with the fuel-lubricated rotary fuel injection pumps. More recent conversions to JP-8 have occurred at Fts. Sill, OK, Riley, KS, and Lewis, WA, with additional conversions scheduled for Fts. Polk, LA, Stewart, GA, Drum, NY, Campbell, KY, Carson, CO, and Bragg, NC.

In those instances where JP-8 is to be additized with the increased treatment levels of MIL-I-25017 recommended above, the treated JP-8 should not be used in aircraft until testing has been done to assure its acceptability.

Recent technical publications covering the issue of diesel fuel lubricity and its testing methodology in considerably greater detail are found in the following SAE publications:

- SAE Technical Paper 950248 entitled "Diesel Fuel Lubricity"

- SAE Technical Paper 952369 entitled "Survey of Low Sulfur Diesel Fuels and Aviation Kerosenes From U.S. Military Installations"

Both of the above documents are excellent reference sources and should be consulted for additional information.

The above **"interim lubricity requirements"** reflect a coordinated Mobility Technology Center-Belvoir and TARDEC Fuels and Lubricants Research Facility position.

12 September 1995

SERVICE BULLETINS ON ROTARY FUEL INJECTION PUMPS

SERVICE BULLETINS ON ROTARY FUEL INJECTION PUMPS

Use of JP-8 or JP-5 in diesel fuels vehicles and equipment has in the past resulted in same operational difficulties and problems that were subsequently found to be not related to the fuel being consumed. These operational difficulties and problems have occurred predominantly in fuel-lubricated rotary-type injection pumps used in General Motors 6.2L and 6.5L diesel engines.

Although JP-8 or JP-5 were prematurely blamed for some of these problems, subsequent investigations revealed that particular factory recommended parts change-over had been issued but not implemented. These factory recommended change-over procedures had been issued by component manufacturers to correct a materials or design deficiency, or to better accommodate using lower viscosity fuels. In numerous instances, these recommended parts changeover procedures had not been implemented as the information had not gotten to the field.

Copies of the following relevant Stanadyne Automotive Service Bulletins are provided:

- Service Bulletin No. 484R4 — Hot Engine Restart Complaints for GM 6.5L DB2 Equipped Applications

- Service Bulletin No. 284R2 — Standardization of Elastomer Insert Drive (EID) Governor Weight Retainer Assemblies

- Service Bulletin No. 125R4 — Field Conversions for Low Viscosity Fuel Operation

NO: 484R4

STANADYNE
Diesel Systems

SERVICE BULLETIN

LIMITED
DISTRIBUTION

DATE: August 10, 1995

SUPERSEDES: S.B. 484113 dated 1/8/95
and S.L. 289 dated 8/9/94

LIMITED DISTRIBUTION — GENERAL MOTORS

SUBJECT: HOT ENGINE RESTART COMPLAINTS — GM 6.5L DB2 EQUIPPED APPLICATIONS

**MODELS AFFECTED: DB2-4911, 4927, 4970, 4971, 5079, 5088
5089, 5119, 5129, 5149 AND 5157**

There have been a number of hot engine restart complaints on GM 6.5L DB2 applications with the affected pump models, particularly in areas where ambient temperatures are high and generally following an engine shutdown period of approximately 15-30 minutes. Effective with pump serial number 7768648, Stanadyne began utilizing a new Hydraulic Head and Rotor Assembly, PIN 31506, to address this condition. The 31506 H&R contains design changes which improve the cranking efficiency with hot and/or lower viscosity diesel fuels and it supersedes the original H&R assembly, PIN 29124. It is important to note that only a small percentage of the 1992 and 1993 6.5L diesels have verifiable hot starting conditions which require the H&R change.

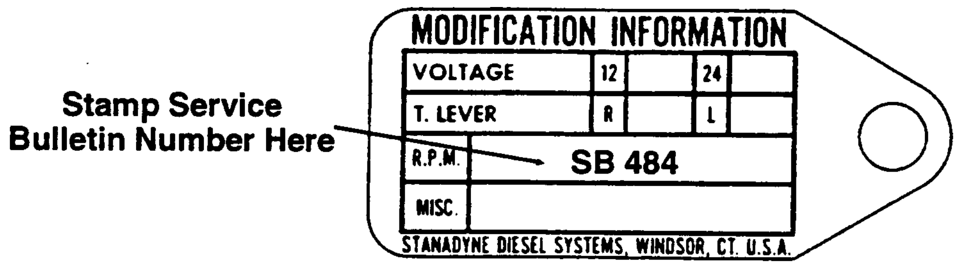
In previous issues of this bulletin Stanadyne has instructed the service network to install a replacement Head and Rotor assembly into the pumps (P/N C1506 which is the remanufactured version of P/N 31506) without testing the pumps as received to determine whether they meet minimum cranking fuel requirements. **Stanadyne will now revert to normal warranty procedures where the pump must be tested as received. If the pump meets the minimum cranking delivery specifications, regardless of which H&R it contains, it must either be returned to the customer without further repairs being made or if the customer wishes, a C1506 H&R may be installed but will be chargeable to the customer (the GM Dealer performing the diagnostics and pump removal and reinstallation) - whether the pump is within the Stanadyne warranty period or not.** NOTE: In Canada where a DB2 exchange program is in effect for General Motors, dealers are to issue exchange units as they normally would, but pumps which pass the test as received criteria are to be overhauled *without the addition of the C1506 H&R assembly* and the claim marked "Fault Not Found".

As a result, a C1506 Head and Rotor may only be installed into pumps and a claim submitted to Stanadyne when the pump fails to meet the minimum

Diesel Systems Division, Stanadyne Automotive Corp.
92 Deerfield Road, Windsor, CT 06095, USA Tel: (203) 525-0821; Telex: 99218; Telecopy: (203) 525-4215

cranking delivery test and is within the 3 year/50,000 mile (80,000 km) Stanadyne warranty period.

When one of the affected pump models is upgraded with a C1506 H&R to address a hot, hard starting complaint, it must be identified by stamping "SB484" in the miscellaneous section of a 30607 Stanadyne Modification Nameplate as shown below and then affixing the plate to the pump under the rear governor cover screw as outlined in Service Bulletin 486.



Modification Nameplate 30607

Warranty
If one of the affected DB2 model injection pumps is received for a complaint of hard starting hot, and fails to meet the minimum cranking delivery specification when tested as received, and is within Stanadyne's warranty period of 3 years or 50,000 miles (whichever comes first), Service Dealers may submit a warranty claim for up to 3.7 hours labor broken down as follows:

Labor Operation No.	Description	Allowance (Hours)
00	Administration Time	0.5
01	Test as Received	1.0
50	Disassembly, Reassembly	1.2
51	Calibration	1.0
	TOTAL:	3.7

Please circle Class Code 3 and reference S.B. 484 on your warranty claim form. Canadian Service Dealers may submit a claim for overhauling the pump for their exchange unit shelf stock as outlined in Service Letter 273C.
NOTE: Only remanufactured H&R assemblies (P/N C1506) are to be used for this repair when performed within the Stanadyne warranty period.

Technical Support Group
Product Support Department

NO: 284R2

STANADYNE Diesel Systems

SERVICE BULLETIN

Date: January 30, 1993 **Supersedes: S.B. 284R1 and S.B. 284A**

SUBJECT: STANDARDIZATION OF ELASTOMER INSERT DRWE (EID) GOVERNOR WEIGHT RETAINER ASSEMBLIES

As you may know, Stanadyne first introduced EID governor weight retainers in 1985 for certain automotive pump applications and recently began utilizing EID weight retainers on all tang driven DB and DB2 applications, both automotive and non-automotive.

Stanadyne has now designed and released three additional EID weight retainers for spine driven DB and DC pump applications. These spine and tang driven-type EID weight retainers supersede all previously used flex ring and welded governor weight retainer assemblies.

The following chart provides the complete list of available EID weight retainers and supersession information:

EID WEIGHT RETAINER ASSEMBLIES

Tang Drive			
Part Number	**Description**	**Identification**	**Supersedes**
28089	Large Heel Radius, Copper Plated	None	None
28370*	Large Heel Radius	None	18987, 22940, 23375
28681	Large Heel Radius, Nickel Plated	R	20235
29111	Sharp Heel Radius	L	19528, 23853, 23376
Spline Drive			
Part Number	**Description**	**Identification**	**Supersedes**
29294	Large Heel Radius	None	19537
29295	Sharp Heel Radius	L	19541, 19542
29296	Large Heel Radius, Nickel Plated	R	20228

* Supplied for service in Kit 27984 which originally contained EID weight retainer assembly 24295 (Ref. S.B. 426).

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Identification

EID weight retainer assemblies are identified in the following manner:

Large heel radius:	No identification mark (previously marked "CL" on weight retainers prior to the EID version).
Sharp heel radius:	Stamped "L" on the flat surface area of the retainer between the weight sockets.
Nickel plated:	Stamped "R" on the flat surface area of the retainer between the weight sockets.

Flexible Retaining Rings

Although the flex ring governor weight retainer assemblies have been superseded by the EID version, the 22935 flexible retaining ring is still available for servicing these governor weight assemblies. Flex ring replacement instructions are as follows:

Disassembly

To disassemble a retaining ring from a weight retainer, insert the tips of snap ring pliers 13337 under the flexible ring between any two rivets. Expand the pliers while applying pressure in an upward direction. A slight twisting motion will snap the ring off the rivet. The ring may then be pulled by hand from the remaining rivets.

Assembly

To assemble a new flex ring to a weight retainer:

1. Place the weight retainer cage with the three rivets face up on a work bench.

2. Assemble the hub (rivets facing up) to the weight cage.

3. Insert the tips of snap ring pliers 13337 into one of the holes in the new flexible retaining ring, and expand the hole by squeezing the pliers. *Caution: over expansion may damage the ring.*

4. While holding the hub and retainer with one hand, catch the back edge of the hole in the ring under the head of a rivet on the retainer (Figure 1).

5. Pivot the pliers around the rivet until the ring snaps into its groove beneath the head of the rivet.

6. Repeat this process to assemble the ring to the remaining five rivets.

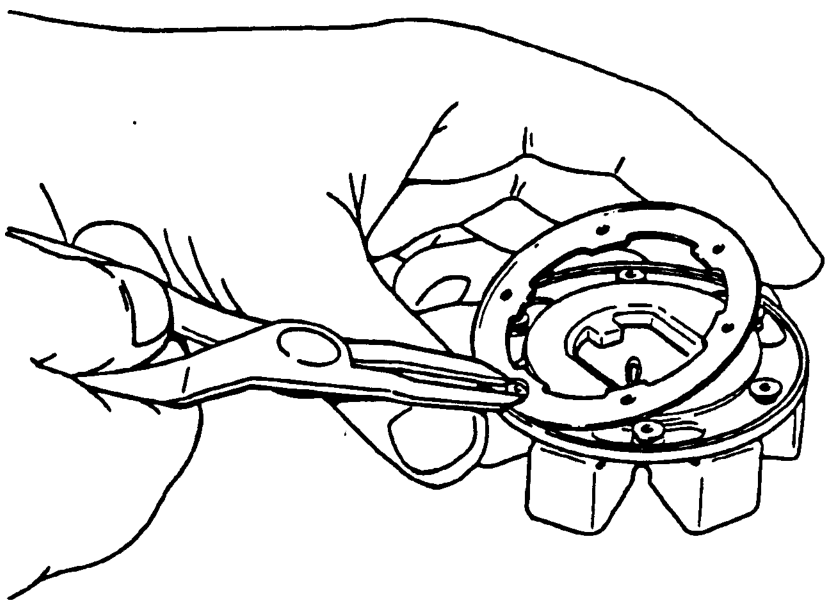

Figure 1

Governor Weight Retainers & Thrust Washers

Weight retainers utilized prior to the EID standardization, were identified by a stamped "L" (sharp corner) or "CL" (radiused corner) in the location as shown in Figure 2. In 1981 the inside diameter of the weight retainer was increased (Ref. Figure 3) to allow for the use of a thrust washer without a chamfered edge and were identified by a stamped line under the "L" or "CL".

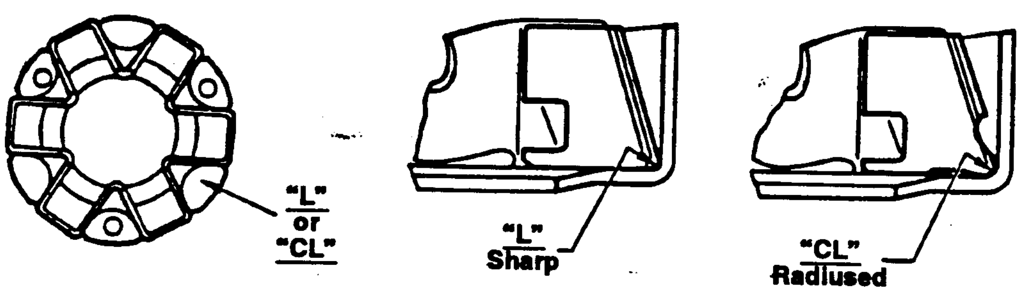

Figure 2

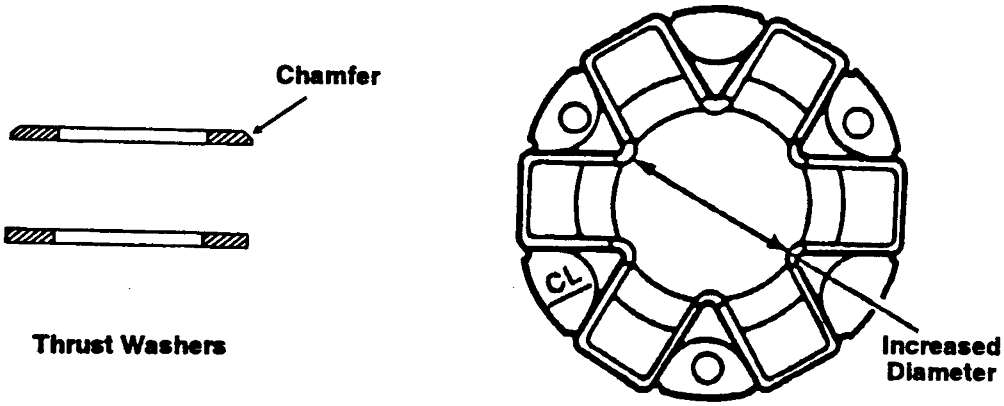

Figure 3

A chamfered thrust washer must be used in conjunction with weight retainers with the smaller inside diameter. This chamfer eliminates the possibility of interference between the thrust washer and the weight sockets when the weights are in their outermost position. ***NOTE:*** *A new plated, chamfered thrust washer, part number 29709, is now available for pumps which are equipped with a small inside diameter weight retainer that operate on lower viscosity fuels (Ref. S.B. 125).*

Un-chamfered thrust washers should be utilized on pumps with increased inside diameter (which includes all EID types) weight retainer assemblies. However, the chamfered thrust washers may be used with all weight retainer assemblies. Thrust washer part numbers and usage is provided in the following chart:

Part No.	Description	Where Used
11620	Chamfered	Smaller inside diameter Weight
29709	Chamfered (Plated)	Retainers (prior to 1981)
20222	Un-chamfered (Plated)	Increased inside diameter Weight
23272	Un-chamfered	Retainers (1981 - present, all EID's)

Technical Support Group
Product Support Department

NO: 125R4

STANADYNE Diesel Systems

SERVICE BULLETIN

DATE: January 8, 1998 **SUPERSEDES: S.B. 125R3 dated 6/1/93**

SUBJECT: FIELD CONVERSIONS FOR LOW VISCOSITY FUEL OPERATION

Stanadyne has compiled the following information for our service network to allow for field conversions of Stanadyne fuel injection pumps for operation with fuels having a lower kinematic viscosity than DF-2.

Stanadyne recommends the use of special transfer pump and drive components to reduce wear and extend the life of the pump when operated with low viscosity fuels. Specially plated governor components, in addition to the transfer pump and drive components, are normally only recommended for applications which are equipped with speed droop governors when operating with these fuels.

Stanadyne has established the following fuel guidelines for operation of our fuel injection pumps with standard and low viscosity components. Whenever a pump is converted for low viscosity fuel operation, it is imperative that the end user understands that the low viscosity fuel components were developed for operation with fuels listed within the recommended and acceptable categories. Fuels listed within the emergency category, such as JP-4, should be used as such, on an emergency basis only.

	FUEL USAGE WITH STANDARD COMPONENTS	**FUEL USAGE WITH LOW VISCOSITY COMPONENTS**
Recommended	DF-2, No. 2-D	DF-2, No. 2-D, DF-1, No. 1-D
Acceptable	DF-1*, No. 1-D*, No. 4-D	JET A, JET A-1, DF-A JP-5, JP-7, JP-8
Emergency Only:	JET-A, JET A-1, DF-A, JP-4, JP-5, JP-7, JP-8, TS	JP-4, TS

* Diesel fuel grade #1 is only acceptable for use with standard components when ambient temperatures are below 32°F (0°C).

Diesel Systems Division, Stanadyne Automotive Corp.
92 Deerfield Road. Windsor, CT 06095, USA Tel: (203) 525-0821; Telex: 99218; Telecopy: (203) 525-4215

NOTE: Home heating oils commonly carry the same No. 1 and No. 2 grade designations as Diesel fuel and often are used interchangeably with those grades of Diesel. Some home heating oils, however, do not contain the necessary additives to provide proper engine operation. It is also illegal in many countries to utilize these oils for over-the-road use when their cost does not include applicable road taxes.

The chart of components which follows will assist in determining which part changes are required to implement these field conversions. Refer to the individual pump specification to identify which standard components have a low viscosity fuel replacement.

LOW VISCOSI'IY FUEL CAPABILITY
CONVERSION PARTS

REMOVE	INSTALL	DESCRIPTION	MODEL TYPE			
			DB	DB2	DB4	DM
20511	20803	Transfer Pump Blades	X	X	X	X
20512 (O' size)	20804	Transfer Pump Blades	X	X	X	X
16753	18958	Transfer Pump Liner	X			
21232	22988	Transfer Pump Liner		X	X	X
11620	29709	Governor Thrust Washer	X	X		
23272	20222	Governor Thrust Washer		X		X
19860	23859	Governor Thrust Washer			X	
21522	24691	Drive Shaft Thrust Washer		X		
26468	26358	Drive Shaft Thrust Washer			X	
26469	26361	Shaft Retaining Ring			X	
10213	29138	Drive Shaft	X	X		
21519	28573	Drive Shaft		X		
23364	24108	Drive Shaft		X		
23452	26110	Drive Shaft		X		
26179	26238	Drive Shaft		X		
26386, 24623	26538	Drive Shaft (Ref. S.B. 419)		X		
28825	23820	Drive Shaft		X		
29783	27639	Drive Shaft		X		
30941	30940	Drive Shaft		X		
30500	31325	Drive Shaft		X		
19870	33817	Rotor Retainer (Note 1)		X		
32859	33818	Rotor Retainer (Note 1)		X		

NOTE 1: P/N's 33817 and 33818 can be used only in pump models with Pressure Compensating Transfer Pumps – Ref. S.B. 444A. These rotor retainers have a notch on the outside diameter to distinguish them from P/N's 19870 and 32859.

ADDITIONAL PARTS FOR APPLICATIONS
EQUIPPED WITH SPEED DROOP GOVERNORS

REMOVE	INSTALL	DESCRIPTION	MODEL TYPE			
			DB	DB2	DB4	DM
12214	20224	Pivot Shaft	X	X	X	X
12358	20225	Linkage Hook Link	X	X	X	X
21201	20214	Governor Weight	X	X		
19858	28974	Governor Weight			X	X
22284	23858	Governor Weight			X	X
29135	30800	Governor Weight			X	
28089	28681	Governor Weight Retainer		X		
29294	29296	Governor Weight Retainer (spline)		X		
28370	28681	Governor Weight Retainer		X		
19893	23860	Governor Weight Retainer			X	X
15421	20219	Governor Arm	X	X		
24929	20219	Governor Arm	X	X		
29060	20956	Governor Arm			X	X
21312	14483	Governor Thrust Sleeve	X	X		

Identification

Identify each pump which is converted for low viscosity fuel operation by stamping "LVFC" (Low Viscosity Fuel Components) on the nameplate below the pump model number.

Warranty

Conversions for low viscosity fuel operation are made at the request and expense of the customer and as such, Stanadyne will not accept warranty claims for these modifications.

Technical Support Group
Product Support Department

Revision	Date	Changes
1	12/90	Defined fuel usage for both standard and low viscosity components. Added conversion parts chart.
2	1/93	Updated conversion parts chart, changed nameplate identification from "SB 125" to "LVFC".
3	6/93	Updated conversion parts chart and revised fuel usage recommendations.
4	1/98	Updated conversion parts chart.

FIELD EXPEDIENT ADDITIVE BLENDING GUIDES

FIELD EXPEDIENT ADDITIVE BLENDING GUIDES

Situations have occurred requiring guidance as to how to properly introduce approved additives into bulk fuels. Since the DoD policy is to provide a finished fuel to the field, the guidance that has been provided is viewed as field expedient in nature and something that is not normally used as common practice.

Three (3) Blending Guides were developed to accommodate additizing bulk fuels. These Guides, referenced in the Compendium section of this document, are:

- Field Blending Procedure for Addition of MIL-I-25017 Additives to JET A-1 or Other Bulk Fuels (Under the Compendium, see page 105).

- Field Blending Guide for the Addition of MIL-I-25017 Corrosion Inhibitor/Lubricity Improver to Turbine Fuels for Lubricity Improvement (Under the Compendium, see page 132).

- Field Blending Guide for the Addition of MIL-I-85470 Fuel System Icing Inhibitor (FSII) to JET A-1 or Other Bulk Fuels (Under the Compendium, see page 133).

The first Guide (page 105) was developed during Operation Desert Shield as a field expedient means to introduce MIL-I-25017 into JET A-1 at treatment levels equivalent to those used in JP-8 and JP-5 (i.e., approximately 20-25 ppm).

The second Guide (page 132) was developed in 1995 as a field expedient means to introduce MIL-I-25017 to JP-8, JET A-1, JP-5, or low sulfur diesel fuel at levels substantially higher than normally required (i.e., approximately 250 ppm). These higher treat levels were found needed to improve lubricity deficient fuels for diesel fuel consuming materiel.

The third Guide (page 133) was developed prior to U.S. deployment in Bosnia and provides a field expedient fix for introducing MIL-I-85470 FSII into JET A-1 at specification treatment levels (i.e., approximately 0.10-0.15 vol.%). These three Guides have been recently combined into one document to facilitate their use. A copy of this new document entitled "Guide for Field Blending of Additives of For Winterizing Ground Fuels" dated October 1999 is provided as part of this Compendium (see page 162).

SUITABILITY OF JP-8

FOR

NON TACTICAL

VEHICLES

SUITABILITY OF JP-8 FOR NON-TACTICAL VEHICLES

Army historically has been using commercial ASTM JET A1 year round in Alaska for its diesel powered ground vehicles and equipment since approximately the early 1970s. Refiners supplying arctic grade diesel fuel (DF-A under VV-F-800) found it more economical to furnish a JET A1 that met the requirements of DF-A than to specially process a diesel fuel with the required low temperature properties. Alaska now uses JP8 for all its diesel powered ground vehicles and equipment. This includes their non tactical vehicles and equipment.

Planning for full scale impact-type JP-8 Demonstration at Ft. Bliss, TX, was initiated in January 1988 with actual demonstration starting in September 1988 involving over 2,800 vehicles and equipment with JP-8 being introduced into Ft. Bliss in January 1989. This demonstration also included the non tactical administrative vehicles that supported Ft. Bliss operations.

JP-8 Demonstration ended September 1991 with Ft. Bliss including its Transportation Motor Pool (TMP) consisting of commercial Non-Tactical Vehicles (NTVs) requesting they be allowed continued use of JP-8 in lieu of diesel fuel. Demonstration considered successful as no "documentable" fuel-related problems surfaced relative to both tactical and non tactical vehicles that had operated exclusively on JP-8.

Army's conversion from diesel fuel to JP-8 at other installations increased use of JP-8 by administrative vehicles at TMPs prompting GSA to refuse any warranty claims on their leased administrative vehicles. Issue subsequently resolved as GSA agreed to negotiate with individual installations on any fuel-related problems that might occur from using JP-8.

Since that time (ca 1991-1992), several TMPs at different Army installations have continued to use JP-8 in lieu of diesel fuel for operation of their NTV fleet with no operating problems being reported. In particular, the TMP at Ft. Bliss has the longest period of JP-8 being satisfactorily used in its NTV fleet (i.e., approximately some 11 years).

Air Force bases in Korea surfaced problems in Jul. 1995 with using JP-8 occurring principally in their Korean manufactured NTVs. Problems never fully quantified or resolved as Air Force was unable to provide adequate documentation or failed components (e.g., fuel injection pumps) for failure analysis to validate claims being made. Issue left unresolved as Air Force converted back to diesel fuel for their ground vehicles.

Army forces in Korea (19^{th} TAACOM) initiated a test in December 1998 involving some 100 NTVs at two locations to assess whether JP-8 could be satisfactorily used without creating any operational problems. Testing was completed after some twelve months of operating exclusively on JP-8 with no significant problems being experienced. Based upon these and previously reported results, Army is in progress of converting its NTV fleet in Korea from commercial diesel fuel to JP-8.

.

HOT WEATHER OPERATIONAL CONCERNS WITH USING JP-8

INFORMATION PAPER

SUBJECT: High Temperature Operational Concerns with Using JP-8

PURPOSE: To provide information regarding the subject concerns

BACKGROUND: Recent communications from Army Logistic Assistance Representatives in Europe brought attention to "hot restart problems" that High Mobility Multipurpose Wheeled Vehicles (HMMWVs) have been experiencing, reportedly worldwide. After the engine reaches operating temperature and is shut down, subsequent attempts in restarting become difficult if not impossible. Reports of these problems have surfaced from locations in Bosnia, Kosovo, Kuwait, and Germany as well as in CONUS locations such as Ft. Hood, Ft. Bragg, Ft. Lewis and Camp Shelby. The problems appear to be more prevalent in areas where high ambient temperatures are experienced.

FACTS:

- The current mix of fielded HMMWVs worldwide more than likely consists of those powered by both GM 6.2L and GM 6.5L engine systems. Both of these engines are equipped with Stanadyne's DB Series Type Rotary Distribution Fuel Injection Pump. With the earlier GM 6.2L engine, there had been two (2) ***Service Bulletins*** issued by Stanadyne to improve performance. ***Service Bulletin 284R2*** titled "Standardization of Elastomer Insert Drive (EID) Governor Weight Retainer Assemblies" replaced a Flex Ring (containing Neoprene) and retainer assembly with a spline and tang driven retainer assembly. Operating HMMWVs with the fuel injection pump equipped with the earlier Flex Ring component in areas of high ambient temperatures created operating problems due to the deterioration of the Neoprene material regardless of the fuel being used. ***Service Bulletin 125R4*** titled "Field Conversions for Low Viscosity Fuel Operation" provides special transfer pump and drive components as well as specially plated governor components. These components were designed to be used for operating Stanadyne fuel injection pumps with fuels having a lower viscosity than 2-D diesel fuel, and provided some relief in combating the low lubricity and wear problems typically associated with low lubricity and/or very low sulfur containing fuels.

With the GM 6.5L engine, there have also been two ***Service Bulletins*** that Stanadyne issued. ***Service Bulletin 125R4*** mentioned above is intended for the GM 6.5L as well as the GM 6.2L engine. ***Service Bulletin 484R4*** titled "Hot Engine Restart Complaints – GM 6.5L DB2 Equipped Applications" provided a new Hydraulic Head and Rotor assembly designed to improve the cranking efficiency with hot and/or low viscosity diesel fuels and was issued to reduce hot engine restart problems that had principally surfaced with GM 6.5L engine powered commercial vehicles that were being operated in high temperature areas such as Texas. Although no ***Service Bulletin*** was ever issued to parallel the same fix (i.e., Service Bulletin 484R4) for the GM 6.2L engine (as it was no longer in production), the same Rotor and Hub fix has been adapted for the GM 6.2L engine. The typical Stanadyne DB Series Fuel Injection Pump used in the GM 6.2L powered HMMWV is Model Number –4878. Per ECN# 22902, the specification for that pump was revised on October 17, 1994. This revision added the Hub and Rotor part number 31816. The sleeve in the Hub and Rotor is the same as is used in the version for the GM 6.5L engine.

- The purpose in commenting on these above ***Service Bulletins*** is to (1) insure that field personnel are made aware of their existence and, (2) explain the absence of the Hub and Rotor retrofit systems for both the GM 6.5L and 6.2L (i.e., not having implemented ***Service Bulletin 484R4***) will certainly contribute directly to the subject problem. This is supported by the findings that were generated when U.S. Forces were deployed in Haiti. The hot engine restart problem surfaced with commercial utility vehicles powered by the GM 6.5L engine that Brown and Root were operating. At this point, the existence of the ***Service Bulletin 484R4*** surfaced and maintenance personnel were advised of this fix which corrected the problems. The other ***Service Bulletins*** (i.e., 125R4 and 284R2) are worthy of mention as they would correct fuel related problems other than hot engine restarting. For example, during and following the Desert Shield/Storm Conflict, many if not all the Stanadyne pumps that had failed in JET A1 fueled CUCVs and HMMWVs and had to be replaced were subsequently examined and found to **not have been retrofitted** with either ***Service Bulletins 125R4 or 284R2.***

- During Desert Shield/Storm, U.S. Ground Forces used either a locally refined commercial high sulfur diesel fuel or JET A1. There was a small amount of JP5 that was initially brought in, but the vast majority of ground units that used aviation turbine fuel were using the commercial JET A1 which was being provided by the Saudi government under a host nation support agreement. This point is noteworthy as the JET A1 fuel that was being used had a very low sulfur level and a viscosity that was at or below 1.2 cSt @ 40°C which most fuel injection pump manufacturers require. The absence of any corrosion inhibitor (as is called out in JP-8 and JP-5), the extremely low sulfur value, and the marginal viscosity combined with the dirt contamination problems and the absence of any of the above mentioned retrofit kits having been implemented all contributed to the problems that were subsequently encountered and reported.

- Reviewing the recent email correspondence on this problem revealed a wide variety of field expedient fixes being improvised to maintain operability. Some of these included dumping water on the injection pump, loosening the injector line, replacing fuel shut-off solenoids, adding engine oil to the fuel, unplugging the cold advance solenoid, etc. Although these field expedient fixes certainly reflect ingenuity on the part of many, there are certain things that should be avoided. The addition of water to cool the fuel injection pump was used in Desert Shield/Storm. Subsequent testing by the Army's TARDEC Fuels and Lubricants Research Facility (TFLRF) at Southwest Research Institute revealed this practice of deliberate cooling would lead to thermally induced injection pump seizures (See Letter Report BLFRF-91-007 entitled "Evaluation of Thermally Induced Injection Pump Seizures and the Effects of Lubricating Oil Addition on Aviation Turbine Fuel Lubricity" dated December 1991). Likewise, adding oil or fluids to the fuel did not improve lubricity and could very well lead to increased wear. A copy of this Letter Report can be obtained from TFLRF by faxing a request to commercial (210) 522-3270.

OTHER APPLICATIONS

FOR JP-8

OTHER APPLICATIONS FOR JP-8

For Heating Installations –

On 1 October 1999, EUSA completed conversion of all EUSA's installation heating plants in Korea from diesel fuel to JP-8. This conversion was completed without incident and has significantly improved EUSA's wartime defensive posture by eliminating the need for diesel fuel during contingencies. The only things required for this conversion were pre inspections of the piping systems and of the fittings to check for tightness. No other actions were required.

The process is continuing with the conversion of all USFK installations. Given that the Army's tactical petroleum distribution system can only distribute JP-8, those installations already converted as well as those scheduled for conversion will be able to seamlessly transition form commercial deliveries during armistice to deliveries by tactical delivery systems. Additionally, this conversion of storage systems from diesel fuel to JP-8 has and will also provide additional JP-8 war time storage than can be diverted to combat if necessary.

For Use in Kerosene Heaters –

Questions have frequently been asked as to the advisability for using JP-8 in tent heaters that are designed to burn kerosene. The concerns have ranged from flammability problems to those relating to the toxicity of exhaust gases.

These concerns have been reviewed by those responsible for the development of personnel heaters. The position that has evolved is the following:

The toxicity of combustion gases in heaters is not a problem as long as the heater is ***flued*** (i.e., exhausted to the outside environment).

JP-8 is suitable for use in any ***flued*** (i.e., authorized) heater designated for kerosene, distillate fuel, or multi-fuel use.

Unflued heaters are <u>not recommended for use indoors or in a tent environment</u>.

Additional information can be obtained by contacting the U.S. Army Petroleum Center in New Cumberland, PA. DSN 977-7258/6445/7208, or Commercial (717) 770-7258/6445/7208.

CURRENT ARMY POLICY

GOVERNING USE OF

JP-8+100

<u>CURRENT ARMY POLICY GOVERNING USE OF JP-8+100</u>

Background

The Air Force has developed new JP-8 formulations to improve thermal stability allowing higher fuel operating temperatures in advanced fighter aircraft. The first additive package resulting from this development program, the ***+100 additive***, increases thermal stability of JP-8 by 100°F. This package consists of **25 ppm Antioxidant**, **70 ppm Dispersant/Detergent**, **3 ppm Metal Deactivator**, and **158 ppm Solvent Oil**. Air Force results have established that addition of this +***100 additive*** package to JP-8 cleans internal engine parts during use reducing frequency of engine maintenance and generating considerable cost savings. Extensive testing is continuing at numerous Air Force locations in the U.S. and in the U.K., with over 2,022 fighter, training, and cargo aircraft, and helicopters successfully using JP-8+100.

The Dispersant/Detergent component of the +***100 additive*** permanently disables water separators in fueling systems allowing water to enter aircraft fuel tanks. The Air Force and Navy have been jointly working on development of a "drop in" replacement for filter/separators (F/S) which would be necessary for introducing +***100 additive*** into current fuel distribution/hydrant systems at some point in time in the future.

Status of Air Force Introduction of JP-8+100

- JP-8+100 currently limited to fighter, training, and other aircraft fueled by R9 and R11 refueler trucks that have been modified by having their F/S replaced with Velcon Aquacon cartridges.

- Conversion of all fighter and trainer aircraft was scheduled to have been completed by end of FY 1999.

- Air Force decision was made on not expanding JP-8+100 to large aircraft although testing of C-130's and C-141's has been conducted.

- While JP-8's military specification MIL-DTL-83133E includes provision for the +***100 additive***, current Air Force policy is for the +***100 additive*** to be injected into refuelers at participating locations.

- A solution to the water separation problem looks promising; however, no effort has been planned for applying this technology to automotive water separators.

- No low cost, quick, reliable field test for detecting the *+100 additive* is currently available.

- Current likelihood of ground equipment obtaining JP-8+100 is small as Air Force now injects the +***100 additive*** into JP-8 at refueler truck loading racks.

HQDA sent a policy message in April 2000 to the field following an evaluation of the JP-8+100 in Army systems. Based upon those findings, a “No Use Policy was promulgated. The DALO-ZA Message is attached.

HQDA POLICY MESSAGE

R 141139Z APR 00
FM DA WASHINGTON DC//DALO-ZA//
TO AIG 8823
ZEN/AIG 8824
AIG 12117
AIG 7536
AIG 9004
AIG 7430
INFO RUEADLA/DESC FT BELVOIR VA//CODE 40//
RUEADWD/DA WASHINGTON DC//DALO-TSE//

SUBJECT: POLICY MESSAGE -- JP8+100

A. DIRUSAPC 081700Z JAN 98, SUB: AVIATION JET FUEL ADDITIVE, PLUS 100 (JP8 PLUS 100)
B. DIRUSAPC 151300Z APR 98, SUB: USE OF JP WITH THE +100 ADDITIVE (JP8+100)
C. DIRUSAPC 251830Z FEB 99, SUB: SAB

1. THIS IS A COORDINATED TANK-AUTOMOTIVE COMMAND-RESEARCH, DEVELOPMENT, AND ENGINEERING CENTER (TARDEC), AVIATION AND MISSILE COMMAND (AMCOM), U.S. ARMY PETROLEUM CENTER (USAPC), AND HQDA-DALO MESSAGE.

2. THE ARMY HAS COMPLETED AN EVALUATION OF THE AIR FORCE AVIATION FUEL ADDITIVE "+100" AND WILL MAINTAIN A "NO USE POLICY."

3. TARDEC EVALUATION OF THE "+100" ADDITIVE HAS DETERMINED THAT THE USE OF THIS ADDITIVE IN GROUND EQUIPMENT CAN LEAD TO A FAILURE OF FILTER/COALESCER ELEMENTS. MOREOVER, NO PRACTICAL QUANTITATIVE TEST EXISTS TO DETERMINE THE CONCENTRATION LEVEL OF "+100" IN JP-8. CONSEQUENTLY, ALL U.S. ARMY ACTIVITIES MUST PROTECT THEIR FUEL SOURCES FROM ACCIDENTAL "+100" CONTAMINATION.

4. CONCERNING AVIATION, THE USE OF THE "+100" ADDITIVE IS NOT DETRIMENTAL TO THE PERFORMANCE, RELIABILITY, OR SAFETY OF AIRCRAFT. NONETHELESS, THE INABILITY TO DETECT THE ADDITIVE, THE PROBABLE NEGATIVE CONSEQUENCES IF USED IN GROUND EQUIPMENT, AND THE FACT THAT MANY U.S. ARMY ACTIVITIES ARE USING JP8 FOR BOTH AVIATION AND MOBILITY PURPOSES NECESSITATE CONTINUED ADHERENCE TO A "NO USE"

POLICY.

5. IN THE EVENT OF AN INADVERTENT JP8+100 REFUELING (GROUND OR AVIATION), THE FOLLOWING PROCEDURES WILL APPLY:

A. DOCUMENT THE INCIDENT AND QUANTITY OF JP-8+100 RECEIVED. REGISTER THE INCIDENT WITH THE USAPC SO SYSTEMIC PROBLEMS CAN BE IDENTIFIED AND RECTIFIED. USAPC POC: MR. DEL LEESE, DSN: 977-8580.

B. AN AIRCRAFT CAN OPERATE WITH THIS ADDITIVE WITHOUT RESTRICTION AND WILL BE CONSIDERED "+100" FREE AFTER THREE REFUELINGS WITH JP8.

C. IF CIRCUMSTANCES DICTATE AN AIRCRAFT DEFUELING, TRANSFER THE JP8+100 INTO ANOTHER AIRCRAFT. IF THIS IS NOT POSSIBLE, THE JP8+100 MUST BE TREATED AS A HAZARDOUS WASTE MATERIAL AND DISPOSED OF ACCORDINGLY.

D. FOR GROUND EQUIPMENT, DEFUEL THE JP8+100 AND TREAT AS HAZARDOUS WASTE. AFTER DEFUELING, CONSUME ONE TANK FULL OF JP8, THEN IMMEDIATELY REPLACE FILTER/COALESCER ELEMENTS.

6. POC THIS HEADQUARTERS IS LTC KAZMIERSKI, DSN: 225-9749 OR COMMERCIAL (703) 695-9749.

COMPENDIUM OF RELATED REPORTS AND PUBLICATIONS

JP-8 and Related Technical Reports and Publications

The following is a brief compendium of recent technical reports and publications that cover research, development, testing, and utilization technologies related to JP-8 aviation turbine fuel and its use as an alternate diesel fuel. As new publications and reports are published, these will be added to this compendium.

To obtain copies of those documents for which there is an interest, those individuals should forward their request to either of the following address:

Defense Technical Information Center
8725 John J. Kingman Rd., Suite 0944
Ft. Belvoir VA 22060-6218

National Technical Information Services
U.S. Dept. of Commerce
Springfield, VA 22151

The request should cite the AD Number (Accession Number) where given or the Report Number, Title, Author(s), Date, and Organization. For other publications without AD Number descriptions, the request should be forwarded to the sponsoring organization for appropriate action.

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TITLE: JP-8 and JP-5 as Compression Ignition Engine Fuel

REPORT NUMBER: BFLRF Report No. 192

DATE: January 1985

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DTIC NUMBER: AD A150796

ABSTRACT:

For many years, aircraft turbine fuel JP-5 has been used in diesel engines as an alternate fuel for DF-2, and is listed as such in Army Regulation 703-1. Since 1965, diesel engine endurance tests have been conducted in a variety of compression-ignition engines using JP-5 or JP-8 as the fuel and comparing performances with DF-2. None of these tests showed engine failures or excessive wear attributable to the use of kerosene-type aircraft turbine fuels, although slightly reduced fuel injection delivery volumes and lower power output were experienced in most engines, due to lower viscosity and lower heat content of JP-5 and JP-8 compared to DF-2. These results not withstanding, periodically concerns are raised about the use of JP-5 and JP-8 in diesel engines over long periods in the 500- to 1000-hour time frame, especially in new engine designs. This report is primarily an annotated bibliography of 23 references consisting of technical notes, letters, letter reports, and interim reports, on the subject of using aircraft turbine fuels JP-5 and JP-8 in diesel engines.

TITLE: Comparison of 6.2L Arctic and Standard Fuel Injection Pumps Using JP-8 Fuel

REPORT NUMBER: BFLRF Report No. 218

DATE: October 1986

AUTHOR(S): A. F. Montemayor and E. C. Owens

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DTIC NUMBER: AD A175597

ABSTRACT:

The U.S. Army is investigating the use of MIL-T-83133 JP-8 Aviation Turbine Fuel (NATO F-34) in compression-ignition engines. In previous engine-dynamometer tests, JP-8 was completely compatible with the 6V-53T and NHC-250 engines. Tests with the 6.2L engine, however, indicated that the JP-8 fuel may cause premature fuel injection pump deterioration, resulting in a change in maximum fuel delivery volume and retarding the injection timing, The fuel injection pump manufacturer has experienced premature wear problems with their pumps when operated on low viscosity fuels such as JP-8 and DF-A in cold climates. Now an "arctic" fuel injection pump designed to operate with lower viscosity fuels is offered. The objective of this program was to determine if the arctic pump is superior to the standard pump in its ability to prevent the premature wear with JP-8 fuel observed in the engine-dynamometer testing.

A 200-hour test was run on a bench rig in order to compare the arctic and standard pumps. The pumps were subjected to identical operating conditions, running JP-8 fuel at full rack. Test results indicate that the arctic pump performed better than the standard pump in injection timing change (caused by internal drive tang wear), while the standard pump was better in governor thrust washer wear.

Results also indicate that the arctic and standard pumps experienced the same amount of delivery volume deterioration during the 200-hour test. based on this one test, the arctic pump is superior to the standard pump in JP-8 service. Use of JP-8 fuel with either the arctic or standard pump, however, will produce an initial maximum power loss (due to the lower heating value, viscosity, and specific gravity) and may ultimately produce an additional loss in maximum power due to deterioration of fuel delivery as a result of component wear.

TITLE: Development of Fuel Wear Tests Using the Cameron-Plint High Frequency Reciprocating Machine

REPORT NUMBER: BFLRF Report No. 262

DATE: May 1987

AUTHOR(S): M.D. Kanakia, J. P. Cuellar, Jr., & S. J. Lestz

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DTIC NUMBER: AD A216003

ABSTRACT:

The objectives of this program were to develop laboratory bench fuel-wear test methodology using JP-8 and to evaluate the effects of additives to improve load-carrying capacity of JP-8 for use in diesel-powered ground equipment .

A laboratory test using the Cameron-Plint High-Frequency Reciprocating machine evaluated the effects of various chemical and physical parameters influencing the lubricity of the distillate fuels. The test conditions were determined sufficient to eliminate the effect of fluid physical properties such as viscosity. It was shown that the differences in the intrinsic lubricity of the fuels were due to small amounts of chemical additives. Under such conditions, the test can be used as a screening tool to find additives for enhancement of JP-8 lubricity. The test has potential to ascertain minimum lubricity level for diesel-powered ground equipment if these requirements are verified with field performance data and determined to be different from the Air Force JP-8 specifications.

The dimensionless wear coefficients of Reference No. 2 diesel fuel were shown to be an order of magnitude lower than the jet fuels. In all cases, the wear rates of jet fuels and isoparaffinic solvents were improved by addition of a corrosion inhibitor or antiwear additive to match the lower wear rates of the diesel fuels. Although there was no measurable change in the viscosities of the jet fuel due to additives, the wear rates changed by an order of magnitude.

TITLE: Cost Savings Possible With Air Force Conversion to JP-8 As Its Primary Fuel

REPORT NUMBER: AFWAL-TR-87-2037

DATE: May 1987

AUTHOR(S): Charles R. Martel

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SPONSORING ORGANIZATION: N/A

DTIC NUMBER: Unavailable

ABSTRACT:

JP-4 has been the primary fuel for the USAF since 1951. However, in 1979 the USAF converted to JP-8 as its primary jet fuel for its operations in Great Britain. Recently, the North Atlantic Treaty Organization (NATO) began the switch from JP-4 (F-40) to JP-8 (F-34) as its primary jet fuel. However, JP-4 continues to be the primary USAF jet fuel within the continental United States.

The cost and manpower savings possible by converting from JP-4 to JP-8, as the primary jet fuel for the Air Force, are identified and estimated. The much lower volatility of JP-8, as compared to JP-4, accounts for the anticipated savings. For example, aircraft fuel systems must be purged prior to maintenance, and purging aircraft fuel systems that have contained JP-4 can take hours to days. With JP-8 purging may not even be necessary under most ambient temperatures. Another major savings is the reduced evaporation of JP-8, as compared to the more volatile JP-4. Finally, reduced fatalities and casualty losses resulting from ground and flight accidents are estimated.

TITLE: 10,000 Mile JP-8 Fuel Test of 6.2L Diesel Engine in M1028 CUCV Vehicles

REPORT NUMBER: Final Report

DATE: July 1987

AUTHOR(S): D. E. Goss

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DTIC NUMBER: Unavailable

ABSTRACT:

From the vehicle performance there was no indication of wear in any engine component that resulted in power loss. The drawbar test results at the start of test and end of test were nearly identical, and within the power range anticipated for the engines. Likewise the 1000 mile acceleration/deceleration tests and the vehicle top speed attained on the High Speed Track showed no performance deterioration. Fuel consumption stabilized quickly and improved slightly during the testing.

The JP-8 fuel pumps were calibrated on the high side to compensate for the potential 6% power loss due to the lower heating value of the JP-8 fuel.

TITLE: Military Jet Fuels, 1944-1987

REPORT NUMBER: AFWAL-TR-87-2062

DATE: November 1987

AUTHOR(S): Charles R. Martel

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SPONSORING ORGANIZATION: N/A

DTIC NUMBER: Unavailable

ABSTRACT:

This report consists of a brief history of U.S. military fuels for aircraft turbine (jet) engines and ramjet engines. The report discusses the requirements of past and current U.S. military jet fuel specifications, when and why the specification requirements originated, and the importance of these requirements today. The purpose and origin of the various specification test methods are presented, and an extensive discussion of jet fuel additives is provided.

This report should be of value to anyone involved in research and development, logistics, and use of jet fuels. We hope that it will serve as a handy reference for the jet fuel specialist.

TITLE: MOGAS Consumption by U.S. Forces in Europe

REPORT NUMBER: Letter Report

DATE: December 1987

AUTHOR(S): N/A

PERFORMING ORGANIZATION: Logistics Systems Analyses Office, OASD
Falls Church, VA 22041-3203

SPONSORING ORGANIZATION: N/A

DTIC NUMBER: N/A

ABSTRACT:

NATO nations have agreed to the use of a common grade of jet fuel (F-34) in Europe, which is essentially the same as commercial jet fuel. The U.S. is advocating the adoption of F-34 in place of diesel fuel. In addition, the Services seem to be slowly phasing out the use of MOGAS-powered engines in favor of diesel engines. If these trends continue there is a possibility at some time in the future of using a single grade of fuel on the battlefield, with all the associated logistical and tactical advantages.

TITLE: Laboratory Evaluation of MIL-T-83133 JP-8 Fuel in Army Diesel Engines

REPORT NUMBER: BFLRF Report No. 232

DATE: January 1988

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DTIC NUMBER: AD A205281

ABSTRACT:

To support the need to upgrade aviation turbine fuel JP-8 from "emergency" to "alternate" status for diesel-powered equipment and to further advance its use as a single-fuel concept, four Army diesel engines were evaluated by dynamometer tests in cyclic endurance test procedures using JP-8 fuel and compared to baseline performance using diesel fuel (DF-2).

Results showed the advantages for JP-8 fuel to include:

- Increased engine efficiency at the maximum power conditions
- Lower rate of cylinder combustion chamber deposit formation
- Less contamination of the engine lubricant
- Less wear of the upper ring area
- Lower rate of depletion of the lubricant additives
- Less corrosive wear of the engine bearings
- Fewer deposits on the fuel injectors

Problems discovered by the engine dynamometer tests were:

- Reduced maximum power
- Predicted reduction in the range of vehicles operating on JP-8, which is proportionate to the reduced heating value of JP-8 compared to DF-2

TITLE: Properties of JP-8 Fuel

REPORT NUMBER: AFWAL-TR-88-2040

DATE: May 1988

AUTHOR(S): Charles R. Martel

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SPONSORING ORGANIZATION: N/A

DTIC NUMBER: Unavailable

ABSTRACT:

This report provides a summary of 80 JP-8 jet fuels produced over the time period of August 1984 to April 1988. The data were obtained from the test reports provided by the fuel supplier or receiving terminal. Averages, standard deviations, minimum and maximum values of the various data have been determined and are reported.

TITLE: CONUS JP-4 to JP-8 Conversion Study

REPORT NUMBER: N/A

DATE: June 1988

AUTHOR(S): N/A

PERFORMING ORGANIZATION: Defense Fuel Supply Center Cameron Station
Alexandria, VA 22304-6100

SPONSORING ORGANIZATION: N/A

DTIC NUMBER: N/A

ABSTRACT:

The JP-8 conversion initiative resulted from a Tactical Air Command Required Operational Capability request in 1967 for a safer jet fuel because of combat losses in Vietnam. Over half of our aircraft combat losses during the Vietnam conflict were caused by gunfire-induced fuel fires and explosions. The war fighting enhancements provided by JP-8 are very significant. Testing has demonstrated that JP-8 reduces the probability of gunfire-induced ignition by 31 percent. When ignition does occur, the probability of a sustained fire is 68 percent with JP-4 but only 3 percent with JP-8. In JP-8 tests, 97 percent of the fires lasted less than two seconds because of the low amount of vapors available to feed the fires. Because of the high vapor pressure of JP-4, when ignition does occur, the overpressure created (the force of the explosion) is as much as 260 percent greater than is the case with JP-8. Studies of commercial and military aircraft crashes have shown that the probability of a post-crash fire is 12 percent greater with JP-4 than it is with JP-8 or JET A. It was because of wartime enhancement and safety considerations that we converted to JP-8 or JP-5 in NATO, USSOUTHCOM, and USCENTCOM. The Navy converted all its naval air stations from JP-4 to JP-5 in 1983/84 because of safety concerns, and they were aware of the increase in O&M costs and the impact on supply availability. Further, the commercial airlines use JET A (commercial equivalent to JP-8) because of safety concerns, even though they could purchase JET B (civilian JP-4) at less cost.

TITLE: A Survey of JP-5 and JP-8 Properties

REPORT NUMBER: BFLRF Report No. 253

DATE: September 1988

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DTIC NUMBER: AD A207721

ABSTRACT:

With the help of the Defense Fuel Supply Center, JP-8, JET A-1, and JP-5 samples from worldwide sources, representing tenders of products destined for Department of Defense bases, have been received at Belvoir Fuels and Lubricants Research Facility at Southwest Research Institute for evaluation. Inspection data for each sample on DD Form 250 or other data reporting form were also received and entered into a data base. The evaluation of these samples consisted of a few inspection tests for comparison with the data provided by the supplier, and tests related to the use of these fuels in diesel engines, which were measured cetane number, calculated cetane indices by two methods, net heat of combustion, and kinematic viscosity measurements at 40° and 70°C. The properties of these fuel samples were compared to the requirements of VV-F-800D diesel fuels, grades DF-A, DF-1, standard DF-2, and NATO F-54. Frequency histograms for most of the properties were developed and are presented. The JP-8 and JP-5 fuels meet most of the requirements of DF-A and DF-1.

TITLE: Technical Evaluation of Army Watercraft For JP-8 Utilization In Diesel Engines

REPORT NUMBER: Letter Report

DATE: November 1988

AUTHOR(S): Olga Z. Martinovitch

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SPONSORING ORGANIZATION: N/A

DTIC NUMBER: Unavailable

ABSTRACT:

In support of DoD Directive 4140.43 titled "Fuel Standardization on the Battlefield" of 11 March 1988, the area of Army watercraft was explored in an effort to examine JP-8 as the primary shipboard fuel for diesel engines which presently employ diesel fuel as the main source of energy. Because JP-8 has a much lower flashpoint temperature than diesel fuel, temperature surveys were made aboard selected vessels as follows: 65 Foot Tub, 100 Foot Tug, LSV, LCU 1646, LCM-8.

Findings indicate that JP-8 is not recommended as a primary or alternate fuel for shipboard use based on exposure to high temperatures both in and around engine fuel lines and compartments.

TITLE: Potential Benefits From the Use of JP-8 Fuel in Military Ground Equipment

REPORT NUMBER: BFLRF Report No. 249

DATE: February 1989

AUTHOR(S): A. F. Montemayor, L. L. Stavinoha, S. J. Lestz, and M. E. LePera

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DTIC NUMBER: AD A217860

ABSTRACT:

The United States Department of Defense (DoD) is moving toward the use of JP-8 as a single fuel for use in Europe. Many potential benefits are associated with the exclusive use of JP-8 in U.S. DoD equipment. This study briefly discusses these benefits and provides references for further study. Some of the benefits associated with the use of JP-8 will be immediate, and some will require time to be appreciated. Some benefits will accrue during peacetime operations, and some will be most apparent during times of conflict. As JP-8 finds increasing use in field tests and conversions of military bases, there will no doubt be problems that arise alongside the benefits. Careful weighing of the benefits and problems will ultimately lead to optimal usage of fuel resources and, hopefully, increased readiness. The main benefits associated with the use of JP-8 in military ground equipment are simplified logistics, increased readiness, reduced exhaust emissions, and better lubricant life. The information contained in this report is intended to delineate those areas where the use of JP-8 will prove beneficial and alert those personnel that will be affected by the change.

Introduction of JP-8 into the military system should proceed. The most useful demonstration programs will be operations that involve joint operations of forces to include Army ground and aviation activities. These operations should be monitored for benefits as well as possible problems and the lessons learned applied accordingly.

TITLE: Vehicle Acceleration and Fuel Consumption When Operated on JP-8 Fuel

REPORT NUMBER: BFLRF Report No. 257

DATE: February 1989

AUTHOR(S): E. C. Owens, D. M. Yost, and S. J. Lestz

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DTIC NUMBER: AD A216275

ABSTRACT:

A limited test program (eight combat and tactical vehicles) was conducted to obtain a quantitative estimate of the change in combat and tactical vehicle performance and fuel consumption that would occur when converting the military fleet to MIL-T-83133 JP-8 (F-34) fuel. Data specifically desired included startability and idle quality, acceleration rates, and fuel consumption. Also a comparative assessment of the on-vehicle smoke production capabilities of combat vehicles with the two fuels was desired. As a result of these tests, it was determined that substitution of JP-8 for DF-2 reduced the acceleration rates, and thus power, of all vehicles tested except for the M928 and M1009 vehicles, which improved or remained the same. Also, all vehicles tested, except for the M88A1 recovery vehicle, had fuel consumption increases with JP-8 that were at or below that predicted by the heating value difference between the two fuels. No drivability or idle problems occurred with any of the test vehicles.

TITLE: Evaluation of POL Materials As Fog-Producing Agents

REPORT NUMBER: Report BFLRF No. 261

DATE: February 1989

AUTHOR(S): B. R. Wright and D. M. Yost

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DTIC NUMBER: AD A220942

ABSTRACT:

The lack of adequate smoke with JP-8 in the Vehicle Engine Exhaust Smoke System (VEESS) is detrimental to the effective use of JP-8 as the single battlefield fuel. The VEESS is considered a force multiplier and is very critical in armor strategies. Adaptation of an auxiliary tank containing a POL product that provides adequate smoke is a possible solution. Efforts of this study centered on quantifying the obscuration and persistency of smoke produced by POL products. By quantifying the smoke, POL products could be identified that provided DF-2 smoke levels in VEESS simulators. Several candidates that provided adequate smoke included lightweight and multiviscosity engine lubricating oils. All POL products were examined in a diesel VEESS screener that was developed to emulate actual VEESS parameters.

TITLE: 3AF PROGRAM HISTORY: DF-2 to JP-8 Conversion

REPORT NUMBER: Program Report

DATE: June 1989

AUTHOR(S): CPT John Courtney, SMSGT Terry Flemming, and LTC H. Bartel

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RAF Mildenhall, United Kingdom

SPONSORING ORGANIZATION: N/A

DTIC NUMBER: Unavailable

ABSTRACT:

In compliance with HQ USAFE direction, 3AF undertook a DF2 to 3P8 conversion program. The goals of the program were threefold; first, to remove all DF-2 from Base Fuels Management controlled tankage; second, to operate all vehicles on JP-8; and finally, to use JP-8 as a heating fuel if cost effective to do so. 3AF began to feel its way through the conversion process. Many growing pains regarding JP-8 as a vehicle fuel ended in Aug 88 with the conclusion of a successful JP-8 test. Although the test proved JP-8 did not harm diesel engines, there was some performance degradation in certain UK manufactured vehicles.

The 3AF provided new program direction on 15 Nov 88. The Commander specified that the degraded vehicle performance was unacceptable. Consequently, 3AF enlisted the help of the U.S. Army Belvoir Research and Development Center. In May 1989, the Army team visited the UK and met with vehicle manufacturers and base vehicle maintenance personnel. Their report provided advice which resolved some performance concerns and will guide future UK vehicle acquisition. Ultimately their recommendations will help ensure we select vehicles with diesel engines which will respond well on JP-8.

TITLE: Study of Mechanisms of Fuel Lubricity

REPORT NUMBER: BFLRF Letter Report No. 250

DATE: August 1989

AUTHOR(S): N. D. Kanakia and Cliff A. Moses

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DTIC NUMBER: Unavailable

ABSTRACT:

The experimental approach consisted of friction and electrical contact resistance measurements using a Cameron-Plint high-frequency reciprocating rig to characterize the effect of temperature and additives. It was found that electrical contact resistance was a more sensitive measure than the friction force in assessment of temperature and chemical effects. The friction force decreased as film thickness or the contact resistance increased.

Data on a limited variety of fuels demonstrated the existence of a characteristic temperature range for effective reaction film formation (contact resistance) during the friction tests. This lubricative film did not form below a certain activation temperature in some cases and deteriorated rapidly above a maximum temperature. The temperature range for reaction film formation varied with the fuel, the presence of dissolved oxygen, and the presence of dilinoleic acid (DLA) -- a corrosion inhibitor/lubricity enhancer additive.

Adsorption temperature determinations were made for DLA on iron powder. Results for 10-ppm DLA in n-hexadecane indicate that the DLA does not adsorb appreciably at 30°C, needs an activation temperature to adsorb fully at approximately 50°C, and starts desorbing at temperatures of 90° to 100°C. The desorption is complete in the 150° to 180° range. This trend roughly corresponds to the results seen in the friction experiments.

The results of this study are consistent with the thinking that lubricity in low-viscosity fuels is due to low concentration of polar components that form a think reaction polymer film in the wear area. Preliminary analysis using ESCA and FTIR showed that information can be obtained about the thickness and composition of the film.

TITLE: Use of Aviation Turbine Fuel JP-8 as the Single Fuel on the Battlefield

REPORT NUMBER: Society of Automotive Engineers Paper 892071

DATE: September 1989

AUTHOR(S): E. C. Owens, M. E. LePera, and S. J. Lestz

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DTIC NUMBER: N/A

ABSTRACT:

The U.S. military, as a member of the North Atlantic Treaty Organization (NATO), interchanges fuels and other materials with other member nations throughout Europe. NATO is planning to use a single fuel for all battlefield operations, substituting NATO code F-34 (JP-8) for F-40 (JP-4) in aircraft and for F-54 (diesel fuel) in ground equipment. As part of this conversion process, the U.S. Army has been evaluating the impact of this fuel change on the operation of its diesel-fueled ground equipment. This paper covers some of the initial diesel engine durability testing being conducted and also reports some preliminary data of the operation of selected combat and tactical vehicles on F-34 (JP-8). This work, as well as other projects referenced, was a predecessor to the full conversion of an Army base to JP-8 as a final demonstration prior to the conversion within NATO. Fort Bliss, located near El Paso, TX, was converted to F-34 (JP-8) beginning February 1989.

TITLE: JP-8/JET A Fuel Qualification Tests in Engines Representative or the U.S. Army Stock

REPORT NUMBER: TACOM RD&E Center Report 13473

DATE: November 1989

AUTHOR(S): Arpad Miklos

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Warren, Ml 48397-5000

SPONSORING ORGANIZATION: N/A

DTIC NUMBER: Unavailable

ABSTRACT:

The purpose of these tests was to determine: a. the physical ability of tested engines to use the JP-8/JET A fuel; b. the percentage degradation in performance; and c. possible side effects in the fuel systems due to the lower viscosity (lubricity) of JP-8/JET A fuel. Five engines were installed in dynamometer test cells and the AEP-5 NATO standard test specifications were followed.

The engines selected from the U.S. Army stock represented various open and prechamber diesel engines. Output range of these engines varied from 145-750 bhp.

At the time of the test, JP-8 fuel was not available, so JET A fuel was used which has very similar characteristics. Use of JET A fuel was authorized since it was readily available at a moderate cost. JP-8/JET A fuel has a 6.2% lower heating value per unit volume than the presently used standard DF-2, or the diesel referee fuel (MIL-F-46162C). The five engines tested showed an average of 6% less in power output when using JET A fuel.

The operating range of vehicles with these engines will be about 6% lower when using JP-8/JET A fuel. Leakage rate increased within the injection system, using JET A instead of MIL-F-46162C fuel, due to the lower viscosity of JET A. As a result, depending on their injection system design, the test engines displayed varying rates of power loss. This power loss varied between 1.6-7.8% fuel at 86° fuel temperature. To simulate desert conditions, the engines were also tested at higher fuel temperatures.

TITLE: Effects of NATO Code No. F-34/35, JET A Fuel on the AVDS 1790 RISE Tank Engine

REPORT NUMBER: TTL-88-TCMR-134

DATE: July 1989

AUTHOR(S): Unavailable

PERFORMING ORGANIZATION: Teledyne Continental Motors
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SPONSORING ORGANIZATION: U.S. Army Tank-Automotive Command
Tank-Automotive Technology Directorate
Warren, MI

DTIC NUMBER: Unavailable

ABSTRACT:

INTRODUCTION/CONCLUSIONS — As a result of the North Atlantic Treaty Organization's (NATO) conversion of JP-4 to JP-8 fuel (NATO Code No. F-34/35) and the Department of Defense's recent initiation towards a single fuel on the battle field, the U.S. Army Tank-Automotive Command (TACOM) undertook an investigation in mid-1987 of the effects of the use of JP-8 fuel on the AVDS-1790 diesel tank engines. The goal of the program was to operate the engine on the dynamometer using JP-8 or JET A fuel to determine the effects of the fuel conversion on engine performance in a high ambient temperature environment and on engine durability. The effects of the fuel for cold starting the tank engine would also be tested to complete the investigation.

As a result of this program, the following conclusions were drawn:

- The AVDS-1790 RISE diesel tank engine will sustain a substantial power loss using NATO Code No. F34/35, JET A fuel in place of DF-2, VV-F-800 fuel. The lower power will affect M60 tank performance, adversely affecting the mobility of the vehicle.

- After the completion of a 400-Hour NATO Cycle Dynamometer Endurance Test with JET A fuel at high ambient fuel inlet temperature, the AVDS-1790 RISE tank engine fuel injection components showed no serious wear problems. The injection pump delivery valve seats and the nozzle valve and body showed evidence of cavitation erosion.

- At -25°F, using JET A fuel, the AVDC-1790 RISE tank engine has no starting problem.

TITLE: A Study of Alternative Approaches to Produce Obscuring Smoke With JP-8 in Vehicle Engine Exhaust Smoke System (VEESS)

REPORT NUMBER: Report BFLRF No. 263

DATE: December 1989

AUTHOR(S): B. R. Wright, D. M. Yost, and D. S. Moulton

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DTIC NUMBER: AD A207720

ABSTRACT:

Studies were conducted to evaluate several approaches to form obscuring smoke from diesel-powered armored equipment using JP-8 fuel in the VEESS system. One approach investigated the idea of removing the more volatile fractions from the fuel using a vehicular-installed fractional distillation unit, thus providing a less volatile portion to be used as the smoke agent. Results of this study did indicate the possibility of using the less volatile 20 percent bottoms portion of the base fuel. A second approach was investigated that used blends of JP-8 fuel and 5 percent crankcase lubricant in either the combustion chamber and/or the air induction system. It was thought that this combination of fuel/lubricant would produce a soot-laden exhaust that would provide nucleation sites for fuel vapor condensation. These results were not successful for the fuel/engine system that was evaluated.

TITLE: Field Demonstration of Aviation Turbine Fuel MIL-T-83133C, Grade JP-8 (NATO Code F-34) at Fort Bliss, Texas

REPORT NUMBER: Report BFLRF No. 264

DATE: December 1990

AUTHOR(S): W. E. Butler, Jr., R. A. Alvarez, D. M. Yost, S. R. Westbrook, J. P. Buckingham, and S. J. Lestz

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DTIC NUMBER: AD A233441

ABSTRACT:

A JP-8 fuel demonstration was initiated at Ft. Bliss, TX, to demonstrate the impact of using aviation turbine fuel MIL-T-83133C, grade JP-8 (NATO Code F-34) in all military diesel fuel-consuming ground vehicles and equipment. Three major organizations, one ordnance battalion and two activities with a total of 2807 vehicles/equipment (V/E), were identified as participants in the demonstration program, which is authorized to continue through 30 September 1991. JP-8 fuel was first delivered to Ft. Bliss on 31 January 1989. No fuel storage tank or V/E fuel cells were drained and flushed prior to introduction of JP-8 fuel. This procedure resulted in a commingling of JP-8 fuel with existing diesel fuel. As of 31 July 1990, approximately 4,700,000 gallons of JP-8 fuel had been dispensed to user units at Ft. Bliss and at Ft. Irwin National Training Center (NTC) in California.

Three prevalent perceived areas of concern arose from the beginning of the program: (1) fuel filter plugging, (2) loss of power, and (3) overheating. The use of JP-8 fuel did not cause or exacerbate any V/E fuel filter plugging. All instances of filter plugging were caused by contaminated or deteriorated diesel fuel remaining in the fuel cells. Where power loss was apparent, generally it was commensurate with the difference in heating values between JP-8 and diesel fuel. No instrumentally measured differences in engine operating temperatures supported any claim of overheating. The V/E at Ft. Bliss operated satisfactorily with the JP-8 fuel with no alterations, mechanical or otherwise, having to be made to any engines or fuel systems. Considering all factors, there were no major differences in fuel procurement costs, V/H fuel consumption, AOAP-directed oil changes, and fuel-wetted component replacements; it was therefore judged that there is no cost penalty associated with use of JP-8 in place of diesel fuel in ground equipment. A widespread acceptance by command, maintenance, and user personnel of JP-8 fuel resulted in Ft. Bliss requesting that it be allowed to continue using JP-8 fuel after the demonstration program ends. The reduced capability of JP-8 to produce smoke in vehicle engine exhaust (VEESS) is a concern being addressed outside the current JP-8 Demonstration Program.

TITLE: Field Blending Procedure For Addition of MIL-I-25017 Corrosion Inhibitor/Lubricity Improver To JET A-1 or Other Bulk Fuels

REPORT NUMBER: N/A

DATE: January 1991

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SPONSORING ORGANIZATION: N/A

DTIC NUMBER: N/A

ABSTRACT:

At the request of ARCENT G-4, a Field Blending Procedure for introducing corrosion inhibitor/lubricity improver additives into bulk fuels was developed. The purpose of this procedure was to provide guidance in adding and blending corrosion inhibitor/lubricity improver additives, MIL-I-25017, into JET A-1 fuel to improve its lubricity properties. This procedure is considered a field-expedient method and is not the preferred method of additive addition, which is normally by pipeline injection. The Field Procedure states batch blending of the MIL-I-25017 additive should be performed in fuel transport vehicles (tank trucks, semi-trailers, trucks fitted with tank and pump unit, etc.) or in above ground tanks with bottom discharge. Blending is not possible in collapsible (pillow) tanks and is impractical in collapsible drums or in vehicle/equipment fuel tanks.

TITLE: NATO Pipeline Committee Working Group No. 4 Ground Fuels Working Party Catalogue of Nations' Tests Using F-34/F-35 in Diesel Engines

REPORT NUMBER: Logistic Executive (Army) Ord 2d

DATE: September 1991

AUTHOR(S): LTC R. B. P. Smith (UKAR), Chairman Ground Fuels Working Party

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SPONSORING ORGANIZATION: N/A

DTIC NUMBER: N/A

ABSTRACT:

A compendium of all engine/component testing and field trials being conducted within the NATO countries that involve use of F-34 (JP-8) or F-35 (JET A-1) has been developed. It lists all testing conducted by the fourteen (14) NATO countries. The compendium is updated semi-annually.

TITLE: Fuel Lubricity Requirements for Diesel Injection Systems

REPORT NUMBER: Report BFLRF No. 270

DATE: February 1991

AUTHOR(S): P. I. Lacey and S. J. Lestz

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DTIC NUMBER: AD A235972

ABSTRACT:

The U.S. Department of Defense has adopted the single fuel for the battlefield concept. Diesel fuel will be replaced by JP-8/JET A-1, which has both lower lubricity and viscosity. Currently, the tribological requirements of fuel-lubricated components in the injection system are unknown. As a result, no widely approved lubricity test or standard exists. Similar problems are currently faced in commercial applications where low-sulfur/aromatic fuels are being introduced.

The present study details the wear mechanisms likely to exist with low-lubricity fuels, with particular reference to injection equipment known to be fuel sensitive. The wear mechanism was found to be a function of contact severity and may not be uniquely defined by a single test. A variety of potentially viable laboratory bench lubricity tests is suggested, and fuel/additive components are recommended for wear reduction. Pump stand tests are currently underway to study the correlation of the relatively rapid lubricity bench tests, with full-scale testing.

TITLE: Effects of Oil and Fluid Additions on JP-8/JET A-1 Fuel Properties

REPORT NUMBER: BRDEC Letter Report 91-2

DATE: February 1991

AUTHOR(S): N/A

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DTIC NUMBER: N/A

ABSTRACT:

Since the onset of using aviation kerosene turbine fuels as alternative fuels for diesel/compression-ignition engines, there have been reoccurring reports/claims that certain amounts of either engine oils, transmission fluids, hydraulic fluids, etc. need to be used as a means to improve the "lubricity qualities" of the aviation kerosene turbine fuel (i.e., JP-8, JP-5, or JET A/A-1) and reduce potential wear problems. During Operation Desert Shield, this perceived need to add lubricant/fluid products intensified regardless of numerous messages that were sent recommending against any such action.

Because of the lack of an understanding as to the negative impact any oil or fluid addition can have on the overall performance qualities of the resultant blend, a series of laboratory evaluations was conducted to clearly illustrate the potential harm than can accrue with unauthorized blending of any oil/fluid product into JP-8/JET A-1 fuel.

TITLE: Comparative flammability Testing of JET A-1, JP-5, and DF-2

REPORT NUMBER: Letter Report No. BFLRF-90-0003

DATE: April 1991

AUTHOR(S): B. R. Wright

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DTIC NUMBER: N/A

ABSTRACT:

Back-to-back comparative flammability testing of diesel fuels typically used in Operation Desert Storm were conducted to determine the relative potential safety hazards if JET A-1 is used as a replacement for DF-2 in ground vehicles and equipment. The types of flammability testing that were conducted included both standard tests (flash point, autoignition temperature and hot manifold ignition) and nonstandard tests such as electrical spark ignition, flame propagation rates over liquid fuels and ballistic testing using a 20-mm HEIT round as the ignition source.

Results of this series of tests were presented as three scenarios shown as (1) logistics and handling, (2) general peacetime use, and (3) combat hostilities. It is believed that no increase in hazards would occur during peacetime logistics and handling, slight increase in hazards occurring in peacetime vehicular use, and some increase in hazard in combat where large overwhelming ballistic rounds would initiate a conflagration that would develop faster with the lower flash point fuel. Additional full-scale testing is recommended.

TITLE: Failure Analysis of Fuel Injection Pumps From Generator Sets Fueled with JET A-1

REPORT NUMBER: Report BFLRF No. 268

DATE: January 1991

AUTHOR(S): P. I. Lacey and S. J. Lestz

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DTIC NUMBER: AD A234930

ABSTRACT:

The U.S. Department of Defense (DoD) has adopted the single fuel for the battlefield concept. Diesel fuel will be replaced by JP-8/JET A-1 in compression ignition engines, thereby lowering the fuel logistics burden. These fuels have successfully undergone extensive testing in both the laboratory and in field trials. However, increased failure rates are being reported on a number of fuel-sensitive components during Operation Desert Shield in Saudi Arabia.

Five failed Stanadyne rotary fuel injection pumps were returned to the Belvoir Fuels and Lubricants Research Facility (BFLRF) at Southwest Research Institute (SwRI) for disassembly and post-failure analysis. Particular attention was given to the possible effects of low-lubricity fuel. The results of this investigation indicate that most of the failures may be attributed to causes other than poor fuel lubricity. The reason for failure of specific components in two of the pumps could not be conclusively determined. However, it is believed that they would not have occurred as a result of short-term operation with JET A-1.

TITLE: Wear Analysis of Diesel Engine Fuel Injection Pumps From Military Ground Equipment Fueled with JET A-1

REPORT NUMBER: Report BFLRF No. 272

DATE: May 1991

AUTHOR(S): P. I. Lacey

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DTIC NUMBER: AD A239022

ABSTRACT:

The U.S. Department of Defense has adopted the Single Fuel for the Battlefield concept. During Operation Desert Shield/Storm, JET A-1 replaced diesel in many applications. A simultaneous increase in fuel injection pump failures was observed during that operation. Prior to its introduction, a number of studies bad indicated that JP-8 is compatible with the current fleet of ground equipment. This report forms part of an ongoing study to define the fuel lubricity requirements of ground equipment. The report also details the wear and failure mechanisms observed from used pumps. The results indicate that, although JET A-1 does increase wear, many other failure mechanisms are also prevalent.

TITLE: The Relationship Between Fuel Lubricity and Diesel Injection System Wear

REPORT NUMBER: Report BFLRF No. 275

DATE: December 1991

AUTHOR(S): P. I. Lacey

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DTIC NUMBER: AD A247927

ABSTRACT:

Use of low-lubricity fuel may have contributed to increased failure rates associated with critical fuel injection equipment during Operation Desert Storm. However, accurate quantitative analysis of failed components from the field is almost impossible due to the unique service history of each pump. The current report details the results of pump stand tests with fuels of equal viscosity, but widely different lubricity. Baseline tests were also performed using Reference No. 2 diesel fuel. Use of poor lubricity fuel under these controlled conditions was found to greatly reduce both pump durability and engine performance. However, both improved metallurgy and fuel lubricity additives significantly reduced wear. Good correlation was obtained between standard bench tests and lightly loaded pump components. It was noted that high contact loads on isolated components produced a more severe wear mechanism that is not well reflected by the BOCLE.

TITLE: Evaluation of Thermally Induced Injection Pump Seizures and the Effects of Lubricating Oil Addition on Aviation Turbine Fuel Lubricity

REPORT NUMBER: Letter Report No. BFLRF-91-007

DATE: December 1991

AUTHOR(S): P. I. Lacey

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DTIC NUMBER: N/A

ABSTRACT:

The fuel injection pump is a complex system, comprised of many accurately machined parts with close tolerances in a low-lubricity/viscosity fluid. Pump failure, and its prevention, may be conveniently placed into a number of categories. The present study deals specifically with thermally induced seizures and the effects of deliberately including small fractions of lubricating oil in the fuel as a lubricity enhancer. The report concludes that rapid changes in pump temperature, i.e., washing with cold water, will promote instantaneous seizure. Addition of lubricating oil to the fuel is not expected to promote pump seizure, although formulated engine oils may actually increase wear. Most other formulated oils reduce wear, particularly on highly loaded contacts; however, the addition of such oils is unlikely to be the optimum solution.

TITLE: Final Report on Field Demonstration of Aviation Turbine Fuel MIL-T-83133C, Grade JP-8 (NATO Code F-34), at Ft. Bliss, Texas

REPORT NUMBER: Report BFLRF No. 278

DATE: September 1992

AUTHOR(S): W. E. Butler, Jr., R. A. Alvarez, D. M. Yost, S. R. Westbrook, J. P. Buckingham, and S. J. Lestz

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DTIC NUMBER: AD A256945

ABSTRACT:

A field demonstration was conducted at Ft. Bliss, TX, to determine the feasibility of using JP-8 fuel (MIL-T-83133C, NATO Code F-34) in U.S. Army ground combat/tactical vehicles and equipment (V/E) in lieu of DF-2 diesel fuel. The demonstration was conducted during 1 February 1989 through 30 September 1991. The results of the demonstration for the period 1 February 1989 through 31 July 1990 were reported in Interim Report BFLRF No. 264, entitled "Field Demonstration of Aviation Turbine Fuel, MIL-T-83133C, Grade JP-8 (NATO Code F-34) at Ft. Bliss, TX." After 31 July 1990, Operation Desert Shield/Storm resulted in the deployment to the Middle East of over 2,000 of the initial 2,800 plus V/E participating in the demonstration at Ft. Bliss, leaving approximately 750 V/E for the remaining demonstration interval through 30 September 1991. There was no significant return of V/E to Ft. Bliss by the end of the program. However, by that time, it was apparent that initial results reported in Interim Report BFLRF No. 264 were verified during the remainder of the demonstration.

These results were: (1) no statistically significant differences were observed in average fuel consumption rates for combat/tactical V/E when using JP-8 fuel; (2) where power loss was apparent in only a few power-limited engine systems, generally it was commensurate with the difference in heating values between JP-8 and DF-2; (3) no catastrophic failures due to the use of JP-8; (4) all fuel-related problems surfaced by user personnel were resolved by technical consultation or direct comparison tests with DF-2; (5) JP-8 fuel is acceptable for use in military diesel-powered ground equipment systems; and (6) the lack of a capability to produce a persistent smoke screen still prohibited its use in some combat vehicle engine exhaust smoke systems (VEESS).

TITLE: Level Road Acceleration, Fuel Consumption, and Steady-Pull Evaluations Using DF-2 and JP-8 Fuels

REPORT NUMBER: Report BFLRF No. 279

DATE: October 1992

AUTHOR(S): R. A. Alvarez and D. M. Yost

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DTIC NUMBER: AD A259919

ABSTRACT:

Limited evaluations were conducted on the M998 High Mobility Multipurpose Wheeled Vehicle (HMMWV) and the M977 Heavy Expanded Mobility Tactical Truck (HEMTT). The data that these evaluations would yield included startability and idle quality, acceleration rates, and fuel consumption. The previously tested M88A1 Medium Recovery Vehicle was also evaluated. However, these evaluations would determine if a Teledyne Continental Motors-recommended fuel injection and metering pump adjustment would increase performance and allow the engine to achieve its rated horsepower. As a result of these evaluations, it was determined that the conversion to JP-8 from DF-2 increased the acceleration time of both the M998 and M977 vehicles. Also, the fuel consumption increased on both vehicles; however, the increases were below that predicted by the heating value difference between the two fuels. The M88A1 exhibited an increase in power while pulling its own weight after the pump adjustment; however, the power increase was not noticeable while towing the M1A1 tank.

TITLE: Performance of Fuels, Lubricants, and Associated Products Used During Operation Desert Shield/Storm

REPORT NUMBER: Report BRDEC No. 2527

DATE: August 1992

AUTHORS: A. D. Rasberry and CPT J. H. Weatherwax (BRDEC)
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DTIC NUMBER: AD A255633

ABSTRACT:

A data collection survey on fuels and lubricants successes and problems during operation Desert Shield/Storm CODS). Report includes fuel, lubricants and associated products provided by Host Nation. A series of on-site visits were conducted with U.S. Army and Marine units returning from Operation Desert. Shield/Storm to assess user experiences and performance of fuel, lubricants and associated products. A questionnaire was designed and provided prior to each visit. Knowledgeable ODS veterans from supply, maintenance and user units were interviewed. Summarized conclusions on fuel were (1) JET A-1 proved to be a satisfactory fuel for ground vehicles/equipment for units that continued to use it throughout ODS (2) units that had been using JP-8 or JP-5 fuel prior to deployment had significantly fewer problems then first time users (3) insufficient evidence to support JET A-1 was major factor in fuel injection pump failures. Non-related variables (heat, dirt, usage, known defective part) were major contributing factors.

TITLE: Effect of JP-8 Fuel on Material-Handling Engines

REPORT NUMBER: Report BFLRF No. 285

DATE: November 1992

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DTIC NUMBER: AD A261136

ABSTRACT:

The effect of MIL-T-83133C grade JP-8 fuel, with respect to MIL-F-46162C 1% S DF-2, was established for Army Material-Handling Equipment clean-bum diesel engines. The areas investigated included emissions (gaseous and particulate), power, performance, and durability. The engines revealed reduced emissions utilizing JP-8, with an average decrease in power at 5 percent and an increase in fuel consumption of 2 percent. The durability of an Isuzu C-240 engine with JP-8 was enhanced relative to the MIL-F-46162C fuel. Rough-terrain forklifts were evaluated for fuel consumption and power availability while utilizing JP-8 fuel. The results indicated an average 4-percent increase in fuel consumption and a 3-percent mean decrease in vehicular performance.

TITLE: Wear Mechanism Evaluation and Measurement in the Rotary Diesel Fuel Injection System

REPORT NUMBER: Report BFLRF No. 286

DATE: January 1993

AUTHOR(S): P. I. Lacey

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DTIC NUMBER: N/A

ABSTRACT:

Previous studies have demonstrated that the durability of some fuel injection systems on compression/ignition engines is adversely affected by fuels of sufficiently low lubricity. However, no widely accepted lubricity measure is available; indeed the wear mechanisms present have flat been conclusively defined. The results of the present study indicate that oxidative corrosion is the predominant mechanism with very highly processed fuels, resulting in catastrophic wear and rapid failure. A laboratory test procedure directed toward the oxidative wear mechanism was evaluated and a number of modifications suggested. Two closely related laboratory wear test procedures that rely on the transition from mild boundary lubricated wear to adhesive scuffing were also developed. The resulting procedures allow the fuels to be either ranked using a continuous scale or separated using a simple pass/fail criteria. All the procedures are sensitive to the addition of trace quantities of lubricity additives and show directional correlation with refinery severity, as measured by sulfur and aromatic content. As a result, the tests produced excellent correlation with full-scale equipment tests performed at a number of locations, as well as the criteria necessary for oxidative corrosion. However, the scuffing-load tests show greatly increased separation between good and unacceptable fluids compared to the oxidative-corrosion tests. None of the tests predict the increased wear observed for fluids with a viscosity below approximately 19 cSt at 40°C.

TITLE: Use of Aviation Turbine Fuel JP-8 as the Single Fuel on the Battlefield

REPORT NUMBER: SAE Paper No. 892071

DATE: September 1989

AUTHOR(S): E. C. Owens, M. E. LePera, and S. J. Lestz

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DTIC NUMBER: N/A

ABSTRACT:

The U.S. military, as a member of the North Atlantic Treaty Organization (NATO), interchanges fuels and other materials with other member nations throughout Europe. NATO is planning to use a single fuel for all battlefield operations, substituting NATO Code F-34 (JP-8) for F-40 (JP-4) in aircraft and for F-54 (diesel fuel) in ground equipment. As part of this conversion process, the U.S. Army has been evaluating the impact of this fuel change on the operation of its diesel-fueled ground equipment. This paper covers some of the initial diesel engine durability testing being conducted and also reports some preliminary data of the operation of selected combat and tactical vehicles on F-34 (JP-8). This work, as well as other projects referenced, was a predecessor to the full conversion of an Army base to JP-8 as a final demonstration prior to the conversion within NATO. Fort Bliss, located near El Paso, TX, was converted to F-34 (JP-8) beginning February 1989.

TITLE: Jet Kerosene Fuels for Military Diesel Application

REPORT NUMBER: SAE Paper No. 892070

DATE: September 1989

AUTHOR(S): J. N. Bowden, S. R. Westbrook, and M. E. LePera

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DTIC NUMBER: N/A

ABSTRACT:

The United States Department of Defense has proposed the use of one fuel for combat, JP-8, in ground vehicles and equipment as well as in aircraft. To support this proposal, the Defense Fuel Supply Center (DFSC) requested that samples of JP-8, JP-5, and JET A-1 from worldwide sources representing tenders of products destined for DoD bases be evaluated. Properties affecting diesel engine operation, i.e., cetane number, calculated cetane indices, kinematic viscosities at 40° and 70°C, and net heat of combustion were evaluated and compared to the requirements of Federal Specification VV-F-800D and NATO F-54. Several inspection tests were also conducted, and the data were compared to that information supplied by the refiners. A total of 91 samples of JP-8, 2 JET A-1 samples, and 63 JP-5 samples were analyzed. The results showed that a large majority of the samples met the DF-A/DF-1 specification requirements. Frequency histograms and other statistics for many properties are presented.

TITLE: Technology Demonstration of U.S. Army Ground Materiel Operating on Aviation Kerosene Fuel

REPORT NUMBER: SAE Paper No. 920193 (Reprinted from: SP-900, *Alternative Fuels for CI and SI Engines*)

DATE: February 1992

AUTHOR(S): S. J. Lestz and M. E. LePera

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DTIC NUMBER: N/A

ABSTRACT:

A technology demonstration program was conducted by the U.S. Army to verify the feasibility of using aviation turbine fuel JP-8 in all military diesel fuel-consuming ground vehicles and equipment (V/E). Over 2,800 pieces of military equipment participated in a two and one-half year program accumulating over 2,621,000 total miles (4,219,810 km) using JP-8 in combat/tracked, tactical/wheeled, and transportation motor pool vehicles. Over 71,000 hours of operation were accumulated in diesel/turbine engine-driven generator sets using JP-8 fuel. Comparisons of various performance areas with baseline diesel fuel (DF-2) operation were made. Program results showed: (1) there were no statistically significant differences observed in average V/E group fuel consumption between JP-8 and DF-2; (2) where power loss was apparent in only a few power-limited engine systems, generally it was commensurate with the difference in heating values between JP-8 and DF-2; (3) no catastrophic failures due to use of JP-8; (4) all fuel-related problems surfaced by user personnel were resolved by technical consultation or direct comparison tests with DF-2; and (5) JP-8 fuel is acceptable for use in military diesel powered ground equipment systems. Since there were no major differences in fuel procurement cost, V/E fuel consumption, oil analysis program directed oil changes, and fuel-wetted components replacements, it is judged that there is no cost penalty associated with the use of JP-8 fuel. Further, preliminary results generated have revealed the potential for significant reductions in operational costs due to reduced maintenance of fuel systems, fewer replacement of fuel system components, and extending frequency of oil drains. Recommendations are made concerning further changeovers from DF-2 and subsequent JP-8 transitioning to support the Department of Defense directed single-fuel concept.

TITLE: Effect of Low-Lubricity Fuel on Diesel Injection Pumps: Part I - Field Performance

REPORT NUMBER: SAE Paper No. 920823

DATE: February 1992

AUTHOR(S): P. I. Lacey and S. J. Lestz

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DTIC NUMBER: N/A

ABSTRACT:

The U.S. Department of Defense has adopted a concept in which a single fuel is to be used on the battlefield; diesel fuel is to be replaced by JP-8/JP-5/JET A-1 in compression-ignition engines, thereby decreasing the fuel logistics burden. JP-8 fuel has successfully undergone extensive testing in both laboratory and in field trials. However, increased failure rates were reported for fuel-lubricated rotary injection pump components operating on JET A-1 aviation turbine fuel during Operation Desert Shield. The present paper is the first of a pair that describes the disassembly and failure analysis of twelve rotary fuel injection pumps that operated on JET A-1. Three additional pumps from civilian vehicles that had operated on commercial diesel were also disassembled as a baseline for comparison. Each pump had a unique service history, making quantitative comparison difficult. The results of this preliminary investigation indicate that most failures in the field may be attributed to causes other than poor fuel lubricity. Observed pump failure modes ranged from normal wear, to contamination, to catastrophic pump seizure. However, the cause of failure in three of the pumps was not evident. As a result, the possibility that low-lubricity/viscosity has a deleterious effect could not be conclusively eliminated. The effects of low lubricity on pump performance under controlled laboratory conditions is evaluated in a subsequent paper.

TITLE: Effect of Low-Lubricity Fuels on Diesel Injection Pumps: Part II - Laboratory Evaluation

REPORT NUMBER: SAE Paper No. 920824

DATE: February 1992

AUTHOR(S): P. I. Lacey and S. J. Lestz

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DTIC NUMBER: N/A

ABSTRACT:

This paper is the second of a pair that describe the effects of low-lubricity fuels on diesel injection pump performance. The first paper describes the primary failure mechanisms and wear processes in a number of failed pumps that had been removed from both military and civilian vehicles, which had been operated on JET A-1 and diesel fuels. However, the multitude of unregulated parameters in practical operation renders quantitative comparison between different fuels and pump combinations impractical. This paper describes the degradation in pump performance and the wear processes associated with fuels of varying lubricity in the well-defined environment of a pump test stand. The test methodology concentrates on those areas previously demonstrated to be most susceptible to wear. The results indicate that pump durability is reduced by highly refined low-viscosity fuels, but may be successfully counteracted by either improved metallurgy or lubricity additives. The measured wear rate from the full-scale pump stand tests is compared with results from a lubricity measurement technique commonly used in aviation. Based on this comparison, initial criteria for the minimum fuel lubricity requirements of the injection system are suggested.

TITLE: Wear With Low-Lubricity Fuels: Part I - Development of a Wear Mapping Technique

REPORT NUMBER: *Wear*, Vol.160, pp. 325-332

DATE: 1993

AUTHOR(S): P. I. Lacey

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DTIC NUMBER: N/A

ABSTRACT:

Use of low-lubricity fuels such as JET A-1 is now relatively common in military ground equipment, while severe refinery processes such as hydrotreating are removing reactive components from commercially available diesel fuels. Under critical conditions, durability problems with fuel-sensitive equipment are emerging with the use of JET A-1. As a result, a bench wear test that accurately reflects the environment within the fuel injection system is needed. However, a better understanding of the primary wear mechanisms present in the fuel injection system and their relationship with potential bench wear tests is first required.

Wear maps have previously been used to study ceramic materials and to define the wear mechanisms in metallic contacts. This technique systematically produces a data base according to a self-consistent methodology and allows the effects of each contact parameter to be precisely described. This paper, the first of two, details the initial test development required to ensure that the data base is completed according to a single well-defined procedure. The subsequent paper uses the test methodologies and results developed to elucidate the wear mechanisms present in fuel-lubricated contacts and to assist in bridging the gap between laboratory tests and practical applications.

TITLE: Wear With Low-Lubricity Fuels: Part II - Correlation Between Wear Maps and Pump Components

REPORT NUMBER: *Wear,* Vol. 160, pp. 333-343

DATE: 1993

AUTHOR(S): P. I. Lacey

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San Antonio, TX 78228-0510

SPONSORING ORGANIZATION: U.S. Army Belvoir RD&E Center
ATTN: SATBE-FL
Ft. Belvoir, VA 22060-5606

DTIC NUMBER: N/A

ABSTRACT:

Increasingly severe refinery processes are removing many of the compounds necessary for effective lubrication with diesel fuels. No widely recognized lubricity test or standard currently exists relating to the needs of the fuel injection system on compression-ignition equipment. The Ball-on-Cylinder Lubricity Evaluator (BOCLE) is commonly used by the U.S. Air Force to measure aviation turbine fuel lubricity. However, the tribological requirements of fuel-lubricated components in aviation may not coincide with the needs of ground vehicles. This study uses the wear-mapping technique developed in a preceding paper to indicate the significance of the BOCLE test methodology in this context. In particular, the work highlights the effects of various contact parameters on fuel-lubricated wear that are not revealed by the BOCLE results.

Where possible, both the BOCLE and wear map data are compared with the results of full-scale pump stand tests detailed in a previous paper. Additional nonstandard bench wear tests were performed to further evaluate the contact conditions present within the operating pump. The wear mechanisms of each fluid were determined to be a strong function of both metallurgy and contact stress. Moreover, the onset and severity of each wear mechanism appear to be controlled by different fuel properties. As a result, the relative lubricity observed between fuels depends on the test conditions chosen, so it is unlikely that fuel lubricity may be uniquely defined by a single bench wear test procedure.

TITLE: Evaluation of Oxidative Corrosion in Diesel Fuel Lubricated Contacts

REPORT NUMBER: Accepted by *Tribology Transactions,* Paper No. 93017

DATE: March 1993

AUTHOR(S): P. I. Lacey

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SPONSORING ORGANIZATION: U.S. Army Belvoir RD&E Center
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DTIC NUMBER: N/A

ABSTRACT:

Previous studies have demonstrated that the durability of some fuel injection systems on compression-ignition engines is adversely affected by fuels of sufficiently low lubricity. However, no widely accepted lubricity measure is available; indeed, the wear mechanisms present have not been conclusively defined. The results of the present study indicate that oxidative corrosion is the predominant mechanism with very highly processed fuels, resulting in catastrophic wear and rapid failure. Less highly refined fuels contain natural corrosion inhibitors and produce alternate wear mechanisms that may still affect long-term durability. A laboratory test procedure directed toward the oxidative wear mechanism was evaluated, and a number of modifications suggested. The resulting test produced good correlation with the full-scale pump and appeared to correlate with the criteria necessary for oxidative corrosion. However, it is recognized that this single test procedure may not fully define the lubricity requirements of the injection system, particularly in the absence of oxidative corrosion or very highly loaded contacts that are susceptible to adhesive wear and scuffing.

TITLE: Development of a Lubricity Test Based on the Transition From Boundary Film to Adhesive Wear Mechanisms in Fuels

REPORT NUMBER: Submitted to *Lubrication Engineering*, Paper No. 93111

DATE: June 1993

AUTHOR(S): P. I. Lacey

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SPONSORING ORGANIZATION: U.S. Army Belvoir RD&E Center
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Ft. Belvoir, VA 22060-5606

DTIC NUMBER: N/A

ABSTRACT:

More severe refinery practices to remove naturally occurring sulfur compounds are affecting fuel lubricity. A laboratory wear test that accurately defines the lubricating qualities of diesel and kerosene fuels is urgently needed. This paper details the development of two closely related laboratory wear test procedures that predict fuel-related wear, cognizant of the contact conditions in full-scale equipment. Most preceding methodologies measure the wear scar produced under conditions of continuous boundary-lubricated sliding. In contrast, the tests described in the present study rely on the transition from mild boundary lubricated wear to adhesive scuffing to define the lubricating qualities of the fuel. The resulting procedures allow the fuels to be either ranked using a continuous scale or separated using a simple pass/fail criteria. Careful selection of the test parameters produced a sharp change in both friction and wear at the mechanism transition and wide separation between acceptable and unacceptable fluids. Both procedures are sensitive to the addition of trace quantities of lubricity additives and also show directional correlation with refinery severity, as measured by sulfur and aromatic content. As a result, excellent correlation was achieved with full-scale equipment tests performed at a number of locations. However, the correlation for fuels achieved between laboratory wear tests and full-scale equipment falls below a critical viscosity.

TITLE: Diesel Fuel Lubricity

REPORT NUMBER: Society of Automotive Engineers (SAE) Paper No. 950248

DATE: February-March 1995

AUTHOR(S): P. I. Lacey and S. R. Westbrook

PERFORMING ORGANIZATION: U.S. Army TARDEC Fuels and Lubricants Research Facility [TFLRF (SwRI)]
San Antonio, TX 78228-0510

SPONSORING ORGANIZATION: Merger of information sponsored in part by Department of the Army, Mobility Technology Center-Belvoir, Ft. Belvoir, VA; Southwest Research Institute (SwRI); and several commercial companies

DTIC NUMBER: N/A

ABSTRACT:

The United States and Europe are mandating increasingly severe diesel fuel specifications, particularly with respect to sulfur content and, in some areas, aromatics content. This trend is directed towards reducing vehicle exhaust emissions and is generally beneficial to fuel quality, ignition ratings, and stability. However, laboratory studies, as well as recent field experience in Sweden and the United States, indicate a possible reduction in the ability of fuels to lubricate sliding components within the fuel injection system. These factors, combined with the trend toward increasing injection pressure in modern engine design, are likely to result in reduced durability and failure of the equipment to meet long-term emissions compliance. The U.S. Army Belvoir Fuels and Lubricants Research Facility (BFLRF) located at Southwest Research Institute (SwRI) developed an accelerated wear test that predicts the effects of fuel lubricity on injection system durability. This test now has been widely used by fuel, additive, and equipment manufacturers. Several thousand fuel samples have been evaluated to date, and collectively, they form one of the largest databases on fuel lubricity currently in existence. This range of data permits a good overview of the commercially available fuels and confirms a general decrease in fuel lubricity due to increased refining severity. The results indicate that no high-sulfur fuel (> 0.15 mass %) had poor lubricity, while a number of low-sulfur fuels (< 0.05 mass %) did produce unacceptable wear. The lubricity of many highly refined fuels is probably being restored using relatively high concentrations of additive.

TITLE: Effect of Fuel Composition and Prestressing on Lubricity

REPORT NUMBER: Report TFLRF No. 307

DATE: August 1995

AUTHOR(S): P. I. Lacey and S. R. Westbrook

PERFORMING ORGANIZATION: U.S. Army TARDEC Fuels and Lubricants Research Facility [TFLRF (SwRI)]
San Antonio, TX 78228-0510

SPONSORING ORGANIZATION: Department of the Army
Mobility Technology Center-Belvoir
Ft. Belvoir, VA 22060-5843

DTIC NUMBER: AD A297747

ABSTRACT:

Fuel lubricity -- or the ability of the fuel to prevent wear during sliding -- is sensitive to chemical composition. At present, increasingly severe fuel specifications are being implemented to minimize exhaust emissions. The refinery processes needed to achieve these goals are inadvertently removing many of the surface-active components necessary for wear resistance. To compound this effect, engine operating conditions are becoming more severe, fuel injection pressures are increasing dramatically, while uncooled engines that use the fuel as a heat sink are also being investigated. The present study investigates the relationship between previously validated laboratory-scale wear tests and various fuels' parameters. In general, fuel lubricity is found to be adversely affected by decreasing sulfur and aromatics content, and appears to be most closely related to diaromatics. Laboratory wear tests and full-scale equipment tests were performed to define the effects of operating temperature and thermal prestressing of the fuel. The effects of temperature on wear appear to be fuel composition sensitive. Indeed, the corrosion inhibitor additives tested had little effect at high temperatures. As a result, it is likely that conventional laboratory-scale wear tests performed at room temperature may not fully reflect real-world operating conditions.

TITLE: Survey of Low Sulfur Diesel Fuels and Aviation Kerosenes from U.S. Military Installations

REPORT NUMBER: Society of Automotive Engineers (SAE) Paper No. 952369

DATE: October 1995

AUTHOR(S): S. R. Westbrook, et al.

PERFORMING ORGANIZATION: U.S. Army TARDEC Fuels and Lubricants Research Facility [TFLRF (SwRI)], San Antonio, TX 78228-0510; Department of the Army, Mobility Technology Center-Belvoir, Ft. Belvoir, VA 22060-5843

SPONSORING ORGANIZATION: Defense Fuel Supply Center
ATTN: DFSC-I
Ft. Belvoir, VA 22060-6222

DTIC NUMBER: N/A

ABSTRACT:

In support of the Department of Defense goal to streamline procurements, the Army recently decided to discontinue use of VV-F-800D as the purchase specification for diesel fuel being supplied to continental United States military installations. The Army will instead issue a commercial item description for direct fuel deliveries under the Post-Camp-Station (PCS) contract bulletin program. In parallel, the Defense Fuel Supply Center and the U.S. Army Mobility Technology Center-Belvoir (at Ft. Belvoir, VA) initiated a fuel survey with the primary objective to assess the general quality and lubricity characteristics of low sulfur diesel fuels being supplied to military installations under the PCS system. Under this project, diesel fuel delivery samples were obtained from selected military installations and analyzed according to a predetermined protocol. The results obtained from various tests show that the average low sulfur diesel fuel meets military requirements for DF-2 with the exception of lubricity performance. Proposed fuel lubricity requirements for military ground vehicle diesel fuel are presented.

TITLE: Comparison of Diesel Exhaust Emissions Using JP-8 and Low-Sulfur Diesel Fuel

REPORT NUMBER: Report TFLRF No. 308

DATE: November 1995

AUTHOR(S): D. M. Yost and D. A. Montalvo

PERFORMING ORGANIZATION: U.S. Army TARDEC Fuels and Lubricants Research Facility [TFLRF (SwRI)]
San Antonio, TX 78228-0510

SPONSORING ORGANIZATION: Department of the Army
Mobility Technology Center-Belvoir
Ft. Belvoir, VA 22060-5843

DTIC NUMBER: AD A301922

ABSTRACT:

Comparative emission measurements were made in two dynamometer-based diesel engines using protocol specified by the U.S. Environmental Protection Agency (EPA) and the California Air Resources Board (CARB). A single JP-8 fuel with a sulfur level of 0.06 wt% was adjusted to sulfur levels of 0.11 and 0.26 wt%. The emission characteristics of the three fuels were compared to the 1994 EPA certification low-sulfur diesel fuel (sulfur level equal to 0.035 wt%) in the Detroit Diesel Corporation (DDC) 1991 prototype Series 60 diesel engine and in the General Motors (GM) 6.2L diesel engine. Comparisons were made using the hot-start transient portion of the heavy-duty diesel engine Federal Test Procedure.

Results from the Army study show that the gaseous emissions for the DDC Series 60 engine using kerosene-based JP-8 fuel are essentially equal to values obtained with the 0.035 wt% sulfur EPA certification diesel fuel, and that an approximate sulfur level of 0.21 wt% in kerosene-type JP-8 fuel would be equivalent to the 0.035 wt% sulfur reference fuel. Similarly, the regulated gaseous emissions for the GM 6.2L engine using JP-8 fuel are essentially equal to the values obtained with the 0.035 wt% sulfur EPA reference fuel. All sulfur levels of kerosene-type JP-8 fuel up to the 0.30 wt% MIL-T-83133 specification maximum would be equivalent to a 0.035 wt% sulfur EPA reference fuel.

TITLE: Field Blending Guide for the Addition of MIL-I-25017 Corrosion Inhibitor/Lubricity Improver to Turbine Fuels for Lubricity Improvement

REPORT NUMBER: N/A

DATE: October 1995

AUTHOR(S): William R. Williams

PERFORMING ORGANIZATION: Department of the Army
Mobility Technology Center-Belvoir
ATTN: AMSTA-RBF
10115 Gridley Rd., STE 128
Ft. Belvoir, VA 22060-5843

SPONSORING ORGANIZATION: N/A

DTIC NUMBER: N/A

ABSTRACT:

This guide was prepared at the request of the Quartermaster School to provide guidance in adding and blending corrosion inhibitor/lubricity improver additive, MIL-I-25017, into turbine fuels for the purpose of significantly improving fuel lubricity. This is considered a field-expedient method applicable to kerosene base turbine fuels (JET A, JET A-1, JP-5, JP-8) for use in ground vehicles/equipment only. The treated fuels will contain inhibitor/lubricity improver far in excess allowed for aviation use. The decision to treat should be based on feedback from the field or on laboratory test data.

TITLE: Field Blending Guide for the Addition of MIL-I-85470 Fuel System Icing Inhibitor (FSII) to JET A-1 or Other Bulk Fuels

REPORT NUMBER: N/A

DATE: 19 December 1995

AUTHOR(S): Luis A. Villahermosa and William R. Williams

PERFORMING ORGANIZATION: Department of the Army
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ATTN: AMSTA-RBF
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SPONSORING ORGANIZATION: N/A

DTIC NUMBER: N/A

ABSTRACT:

This guide was prepared at the request of the Quartermaster School to provide guidance in adding and blending the Fuel System Icing Inhibitor (FSII), MIL-I-85470, into JET A-1 or other bulk fuels for the purpose of improving the low temperature usability and prevent/hinder ice formation. This is considered a field-expedient method applicable to kerosene base turbine fuels and middle distillate (diesel) fuels that do not already contain any FSII. These fuels include JET A, JET A-1 and diesel fuel.

TITLE: Diesel Engine Endurance Tests Using JP-8 Fuel Blended with Used Engine Oil

REPORT NUMBER: TFLRF Report No. 330

DATE: September 1998

AUTHOR(S): E. A. Frame, D. M. Yost, and C. F. Palacios

PERFORMING ORGANIZATION: TARDEC Fuels & Lubricants Research Facility (SwRI), San Antonio, TX 78228-0510

SPONSORING ORGANIZATION: U.S. Army Tank-Automotive RD&E Center, ATTN: AMSTA-TR-D/210, Warren MI 48397-5000

DTIC NUMBER: 349754

ABSTRACT:

Tests were done to examine the feasibility of disposing of used engine oil from military vehicles by blending it with JP-8 engine fuel to be used in diesel fueled vehicles. Two diesel engines were evaluated in cyclic endurance dynamometer test procedures using JP-8 fuel blended with 7.5% volume of used engine oil that had been filtered. Results were compared to baseline performance using neat JP-8 fuel.

The following major differences were observed when using the blended fuel: (1) significant ashy deposits were found in the pre-combustion chamber of the 4-cycle diesel engine, and (2) indications of imminent exhaust valve burning (i.e., streaking) were found on the exhaust valves in the 2-cycle diesel engine. For both engines, condition was such that continuous use of the 7.5% volume blend would not be recommended. Considering it would take between 19-68 years for an Army engine to reach the end of endurance testing conditions, use of blended fuel once or twice during the year is judged to be acceptable from an endurance standpoint.

Implementation of this technique to dispose of used engine oil would have a two-fold cost savings. The Army would not have to dispose of used oil, and each gallon of used oil consumed as fuel is equal to one less gallon of JP-8 purchased.

TITLE: Heavy Fuel Engine Technology Assessment

REPORT NUMBER: TFLRF Report No. 331

DATE: April 1998

AUTHOR(S): C. F. Palacios, C. D. Wood, and E. C. Owens

PERFORMING ORGANIZATION: TARDEC Fuels & Lubricants Research Facility (SwRI), San Antonio, TX 78228-0510

SPONSORING ORGANIZATION: U.S. Army Tank-Automotive RD&E Center, ATTN: AMSTA-TR-D/210, Warren MI 48397-5000

DTIC NUMBER: 337601

ABSTRACT:

As part of the Military Single Fuel Forward logistics concept, all fuel-consuming equipment should be able to operate using JP-8. For most engine-driven equipment, this necessitates the use of diesel (i.e., compression ignition) rather than gasoline (i.e., spark ignition) engines. Because of the lower power density of diesel engines, especially small engines, some current fielded equipment, as well as new equipment being developed, are not complying with the Single Fuel Forward directive. The intent of this study was to survey existing state-of-the-art heavy fuel (i.e., diesel fueled) engine technology and recommend an approach to DoD for the acquisition of JP-8 capable engines for these applications.

Equipment developers and item managers were surveyed to identify vehicles and equipment currently using gasoline engines, of situations in which engine limitations severely compromise developmental objectives. The characteristics of current state-of-the-art diesel engine technology, along with what might be achievable for military applications, were then compared with these requirements to determine what engine approaches might satisfy the equipment needs.

The final recommendations combines the following three steps to satisfy the requirements of the wide range of DoD engine applications: (1) Modify existing diesel engines to meet weight and power specifications to provide 10,000 DoD engines per year, (2) Design a new engine family utilizing commercial technology for most components to provide 33,000 DoD engine per year, and (3) Design an engine family of very high power density to provide 1,000 engine per year that cannot be produced by the other two previous types.

TITLE: Survey of Low-Sulfur Diesel Fuels and Aviation Kerosenes from U.S. Military Installations

REPORT NUMBER: TFLRF Report No. 335

DATE: October 1999

AUTHOR(S): S. R. Westbrook and M. E. LePera

PERFORMING ORGANIZATION: TARDEC Fuels & Lubricants Research Facility (SwRI), San Antonio, TX 78228-0510

SPONSORING ORGANIZATION: U.S. Army Tank-Automotive RD&E Center, ATTN: AMSTA-TR-D/210, Warren MI 48397-5000

DTIC NUMBER: 366036

ABSTRACT:

In support of the DoD goal to streamline procurements, the Army recently decided to discontinue use of diesel fuel defined by Federal Specification VV-F-800D as the procurement document for diesel fuel being supplied to military installations with the continental United States. The Army has instead issued a Commercial Item Description (CID) for direct deliveries under the Post/Camp/Station (PCS) contract bulletin system.

In parallel, the Defense Fuel Supply Center (DFSC) and the U. S. Army Mobility Technology Center-Belvoir (MTC-B) at Ft. Belvoir VA initiated a fuel survey to assess the general quality and lubricity characteristics of low sulfur diesel fuel being supplied to military installations under the PCS system.

Under this project, diesel fuel delivery samples were obtained from selected military installations and analyzed according to a predetermined protocol. The results obtained from the various sites show that the average low sulfur diesel fuel meets military lubricity requirements for DF-2 with the exception of lubricity performance. Proposed fuel lubricity requirements for military ground diesel fuel consuming vehicles and equipment are presented.

The results of this project will provide the Army with reliable data concerning the quality of fuel at U.S. military bases and the associated potential for fuel-related problems. Samples were taken during the summer of 1994 and the first three months of 1995. A total of 112 fuel samples were received and analyzed.

TITLE: Evaluation of Korean-Manufactured Non-Tactical Vehicle JP-8 Conversion Demonstration Conducted by the 19th Theatre Area Army Command, Korea

REPORT NUMBER: TFLRF Draft Report No. 352

DATE: November 2000

AUTHOR(S): Ruben A. Alvarez, Douglas M. Yost, and Bernard R. Wright

PERFORMING ORGANIZATION: TARDEC Fuels & Lubricants Research Facility (SwRI), San Antonio, TX 78228-0510

SPONSORING ORGANIZATION: U.S. Army Tank-Automotive RD&E Center, ATTN: AMSTA-TR-D/210, Warren MI 48397-5000

DTIC NUMBER: [not yet assigned]

ABSTRACT:

Technical Support was provided to an in-progress non-tactical vehicle (NTV) JP-8 demonstration program. The fleets had been operating on JP-8 fuel at two U. S. Army installations for seven months prior to TFLRF participation. The fuel conversion plan and fleet testing parameters were designed and coordinated by the transportation officer of the 19th Theatre Area Army Command G-4. Therefore, the TFLRF team's main objectives were to evaluate the on-going JP-8 conversion demonstration and assess the feasibility of using JP-8 fuel in lieu of diesel fuel in Korean-manufactured NTVs using the data and information available at the two test sites.

The data which consisted of fuel sample analyses, assessing the lubricity of the JP8 samples, tear-down inspection of the fuel-lubricated injection pumps, and overall vehicle performance, revealed that the Korean-manufactured vehicles were able to utilize the JP-8 fuel without experiencing any operating problems. These Korean-manufactured NTVs had operated on JP-8 fuel for a period of twelve months and had accumulated in excess of one million kilometers without experiencing any fuel-related operational problems. These data confirmed that use of JP-8 in NTVs will align the Eight U. S. Army (EUSA) with the Single Fuel Forward Concept and allow a seamless transition from armistice to was with respect to bulk fuel distribution and improve EUSA's defensive posture.

TITLE: Evaluation of Biodiesel Samples as Fuel Lubricity Enhancers

REPORT NUMBER: TFLRF Letter Report No. 99-088

DATE: May 2000

AUTHOR(S): E. A. Frame

PERFORMING ORGANIZATION: TARDEC Fuels & Lubricants Research Facility (SwRI), San Antonio, TX 78228-0510

SPONSORING ORGANIZATION: U.S. Army Tank-Automotive RD&E Center, ATTN: AMSTA-TR-D/210, Warren MI 48397-5000

DTIC NUMBER: [not applicable]

ABSTRACT:

The use of agriculturally derived fuel components (i.e., biodiesel) is of interest to the military for ground equipment applications. A previous investigation found acceptable performance of methyl soyate and petroleum diesel fuel blends in the following areas: elastomer compatibility, fuel lubricity, and filter and coalescer performance.

However, some diesel fuels and some JP-8 fuels exhibit poor fuel-lubricity characteristics. This investigation focused on determining the effectiveness of various biodiesel fuel blends in enhancing the lubricity of the blended fuels.

It was found that esters of rapseed oil had nearly equivalent fuel lubricity enhancement. However, the ethyl ester variety imparted better lubricity that the methyl ester variety. Most biodiesel samples significantly improved the JP-8 fuel lubricity to a passing result when added at only a 0.5% volume treatment level. Use of the biodiesel blended into JP-8 would inhibit the premature wear that can occur in rotary type fuel lubricated injection pumps.

TITLE: Republic of Korea Marine Corps JP-8 Fuel Interoperability Evaluation

REPORT NUMBER: SwRI Project 03.02768 (File 03.02768)

DATE: December 18, 2000

AUTHOR(S): Ruben Alvarez, Greg Phillips, and CWO4 David Ray

PERFORMING ORGANIZATION: TARDEC Fuels & Lubricants Research Facility (SwRI)
San Antonio, TX 78228-0510

SPONSORING ORGANIZATION: U.S. Naval Facilities Engineering Services Center
Seabee Logistics Center, Port Hueneme CA 93043-4410

DTIC NUMBER: [not applicable]

ABSTRACT:

U.S. Marines came one step closer to increasing their warfighting capability during recent fuel conversion tests that occurred in conjunction with recent maneuvers with the Republic of Korea (ROK) Marines. The purpose of this test was to demonstrate to the ROK Marines the effects and benefits of using JP-8 fuel in their tactical vehicles.

The ROK Marines currently depend on diesel fuel as their primary fuel. The U.S. Marines are in the process of converting from diesel fuel to JP-8 (or JP-5). It is highly probable that during contingency operations, the ROK forces will be fueled from United States Forces Korea tactical fuel systems. This combined test was to give the ROK Marines the confidence to be able to use JP- 8 in place of diesel fuel and for the ROK military to see the advantages and interoperability in using JP-8.

A series of tactical trucks operated by the ROK Marines (i.e., M511 - 2.5 ton and M711 - 5 ton cargo trucks) were converted to operate on JP-8 in lieu of diesel fuel. One of each type vehicle was selected for full throttle accelerations and hot starting evaluations. Additionally, on-board fuel tank evaluations were conducted on all vehicles to assess the before and after conditions of the internal surfaces of the fuel tanks. Fuel consumption was calculated from data obtained during the convoy phase of the exercise. The vehicles, driven by the assigned ROK drivers, were operated on several 95-kilometer convoys to evaluate vehicle response and operability differences, if any when operating with JP-8 fuel. A total of 3,600 kilometers were accumulated in this demonstration without any operational problems occurring. The evaluations and demonstration proved highly successful, as the drivers were all satisfied with using JP-8 in place of diesel fuel.

TITLE: Properties and Logistics of Air Force Fuel: JP-8

REPORT NUMBER: AIAA 2001-0498

DATE: January 2001

AUTHOR(S): Tim Edwards, William Harrison, and Lourdes Maurice

PERFORMING ORGANIZATION: Air Force Research Laboratory (Attention: AFRL/PRSF), SAF Directorate of Science, Technology, and Engineering (Attention: SAF/AQRT), and American Institute of Aeronautics and Astronautics (AIAA)

SPONSORING ORGANIZATION: [not applicable]

DTIC NUMBER: [not available]

ABSTRACT:

The cost of jet fuel is one the largest single expenses in the U.S. Air Force budget. For relatively low-maintenance aircraft such as transports, fuel cost is often the largest fraction of an aircraft's operation and support (O&S) cost, which are typically 60% of an aircraft's life cycle cost. Thus, fuel handling and use is a high-profile concern in the Department of Defense (DoD). Overall, the DoD consumes roughly 5 billion gallons of jet fuel per year. The baseline jet fuel for the Air Force is JP-8, with the Navy using JP-5 on-board ships.

Under the "Single Fuel for the Battlefield" concept (driven by the need to simplify battlefield fuel logistics), the Air Force and Army will use a single fuel, such as JP-8, for all aircraft and ground vehicles. Hence is can be anticipated that the jet fuel usage by the DoD will increase significantly in the future. This paper discusses the current properties and usage of JP-8

The properties presented should be similar to those of commercial Jet A/A-1. It is also expected that the jet fuel properties in 2020 will be similar to current properties, considering that the Air Force inventory will consist mainly of aircraft currently in the inventory, plus the F-22 and the JSF. However, the jet fuel feedstock pool in 2020 will probably include a wider variety of sources including natural gas and coal.

WHITE PAPER

on

SINGLE FUEL FOR THE BATTLEFIELD

Use in Ground Equipment

White Paper on JP-8 as the Single Fuel for the Battlefield Use in Ground Equipment

I. Introduction

On 11 March 1988, DoD Directive 4140.43 (**1**) [2] stated that the primary fuel for the U.S. military will be JP-8. NATO STANAG 4362 (**2**) likewise declares JP-8 as the primary fuel for NATO use. An overview of the issues associated with using JP-8 as the primary fuel for U.S. military ground equipment is presented herein. Where data have been developed, clarifications for those issues are provided.

II. Single Fuel Forward Concept

The single fuel concept for military battlefield operations, also called the Single Fuel Forward, grew out of solutions proposed by the Air Force and the Army to separate fuel problems.

A. USAF Conversion from JP-4

During the late 1970's, the Air Force began a conversion of their aircraft from JP-4 (F-40) [3] to JP-8 (F-34) to improve the availability of fuel and enhance operational safety.

B. USA-Europe F-65 History

During the mid- 1980's, unusually cold winters in Europe, combined with the introduction of turbine engine-powered ground equipment, caused operational problems in diesel-fueled ground vehicles and equipment. The problems occurred due to the waxing of the fuel along with an increase in viscosity, which led to poor atomizer performance at start-up for the M1 Main Battle Tank. The Army initially resolved this by combining JP-8 and diesel fuel DF-2 (F-54) in a 1:1 ratio which was called the "M1 fuel mix." This fuel blend later became adopted by NATO and was designated F-65. Ultimately, the conversion to JP-8 for year-round use resolved the M1 cold starting issue and eliminated the need to store and blend fuels.

C. NATO Implementation of the Single Fuel Concept (**3**)

AC/112 (WG4) Ground Fuels Working Party of the NATO Pipeline Committee initially investigated the applicability of JP-8 or commercial JET A-1 (F-35) to compression ignition (diesel) engines in land-based vehicles and equipment. Nations performed extensive tests and trials of kerosene type fuels in compression ignition engines, measuring the effects on engine and fuel-related component performance. The advantages and disadvantages of a single fuel were investigated. Where technical problems were identified, solutions have been developed to allow practical use of JP-8 in compression ignition engines in ground equipment on the battlefield. All NATO nations have ratified and are implementing STANAG 4362.

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[2] Bold numbers in parentheses denote references at end of paper.
[3] See Attachment A for fuel definitions used throughout this paper. Additionally, abbreviations and acronyms used but not identified in the text are defined in Attachment B.

Implementation stages of the Single Fuel Concept have been identified.

Stage 1: Replace JP-4 with JP-8 in land-based military aircraft.
Stage 2: Replace diesel fuel with JP-8 in compression ignition/turbine engine equipped land-based equipment.
Stage 3: Eliminate gasoline on the battlefield.

Stage 1 implementation is complete. Stage 2 implementation is in progress with problems and solutions identified.

III. What does JP-8 use mean for ground equipment?

A. Fuel Cleanliness

As an aviation turbine fuel, JP-8 is more highly refined than diesel fuel, with a cleanliness specification for particulate matter of 1.0 mg/L maximum, versus the diesel fuel (DL-2) particulate matter requirement of 10 mg/L maximum. This inherent aviation fuel cleanliness will result in longer fuel filter replacement intervals compared with DL-2. The water reaction interface rating and the water separation index specifications for JP-8 will result in reduced water entrainment or emulsification, which could result in less fuel system corrosion, and reduced potential for microbiological growth compared to DL-2.

B. Fuel Storage/Thermal Stability

The storage stability of JP-8 makes it a better fuel for extended storage or use in pre-positioned vehicles. Highly refined JP-8 is much more thermally and oxidatively stable than DL-2. This reduces the formation of fuel deterioration by-products often formed during the long-term storage of diesel fuels. The Fuel System Icing Inhibitor (FSII) in JP-8 also affords increased protection against microbiological growth since FSII acts as a bio-stat. This is important for equipment like the M1 tank, where fuel deterioration and microbiological contamination in the front fuel cell are continuing problems. Unlike DL-2, the JP-8 specification also contains a thermal stability requirement that provides lower diesel and turbine engine injection system nozzle fouling and fewer fuel system deposits (**4**).

C. Fuel Handling, Distribution, and Safety

While JP-8 has a somewhat lower flash point than DL-2, both are considered non-volatile. Because of the presence of the required additives, conversion to JP-8 has often been accompanied by a short-term increase in fuel filter plugging as the fuel removes previously-deposited debris present in the diesel fuel system. After this initial system cleanup, the higher cleanliness requirements needed for aircraft use reduce any further fuel filter plugging and water contamination, resulting in a decrease in maintenance costs.

The cloud point of diesel fuels, when wax crystals form, varies with the season and fuel grade, and typically ranges from -45°C (DL-1 minimum) to -3°C (DL-2 maximum) [4], while the freezing point for JP-8 is dictated to be no higher than -47°C. The freezing point of a fuel is the temperature at which all precipitated wax crystals in the fuel disappear upon warming. Since the freezing point of

[4] From **Diesel Fuel Oils**, 1994, Cheryl L. Dickson and Gene P. Sturm, Jr., NIPER, December 1994.

JP-8 is much lower than temperatures ever encountered by ground equipment, fuel starvation due to waxing is eliminated with JP-8, thus removing an operational problem encountered by ground equipment, particularly during rapid climate changes or when shipping equipment from one region of the world to another.

D. Fuel System and Elastomers

JP-8 has a composition very similar to conventional diesel fuel, in particular resembling it in aromatic content more closely than do several new low emission diesel fuel formulations. As a result, fuel system elastomers and seals are unaffected by the conversion from diesel to JP-8.

E. Combustion and Emissions

The ignition characteristics of fuel for compression ignition engines are defined primarily by cetane number, which is a measure of the tendency to auto-ignite. Other than differences resulting from cetane number variation, JP-8 and DL-2 have identical combustion characteristics. Emissions with JP-8 and DL-2 are equivalent, with the EPA approving the substitution by the DoD of JP-8 for DL-2 for both on- and off-highway use (**5**). The somewhat higher sulfur-based particulate from the slightly higher allowable sulfur levels in JP-8 is offset by lower particulate due to the reduced average boiling point and lower aromatic concentration. JP-8 burns neither hotter nor slower than DL-2. In diesel engines the lower JP-8 viscosity, higher volatility, and lower cetane number result in better atomization and more premixed combustion, with slightly improving thermal efficiency compared with DL-2 (**6**).

F. Diesel Engine Fuel Injection Systems

Virtually all the vehicle operating differences observed between JP-8 and diesel fuels are the result of the way in which diesel engine fuel injection systems respond to changes in fuel physical properties. Fuel is injected into the diesel engine combustion chamber at high pressure through an atomizing nozzle, using a (complex) variant of a piston pump (barrel and plunger). The injection pump supplies a precisely metered amount of fuel to each engine cylinder, at pressures between 5,000 and 24,000 psi, with the beginning of fuel injection precisely timed to within one degree of crankshaft rotation. While the injection systems meter fuel based on volume, the combustion process is controlled by the mass of fuel injected.

Fuel density influences the injection process and engine performance by altering the mass of fuel delivered during the effective metering and injection stroke. For the same effective metering and injection stroke, less mass of JP-8 fuel than DL-2 is injected, but the injection pressure is similar because all hydrocarbon fuel have virtually the same compressibility.

Changes in fuel viscosity alter the fuel injection process, despite how this physical property of the fuel is varied. Viscosity variations due to fuel types (e.g., JP-8 and DL-2) and viscosity variations due to temperature will have the same impact on the dynamics of the fuel injection process. Most of the injection changes result from differences in the internal leakage from the high pressure regions of the pump and injection nozzle. The fuel injection system internal leakage reduces the mass of fuel metered into the combustion chamber during the injection process.

When changing to lower viscosity JP-8, the design configuration of the fuel injection system has a major impact on any change in the peak power available from the engine due to the number of high pressure leakage paths. Table 1 summarizes the general effects of different injection system designs.

Table 1. Impact of Reduced Viscosity Changing from DL-2 to JP-8

Type of Injection System	Metering process	High Pressure Leakage
Unit Injector fill metering	Fuel delivery increases Timing advances	Single Leak path
Unit injector - spill metering	Fuel delivery decreases Timing unchanged	Single Leak path
In-line Pump & Nozzle	same as Unit Injectors	Two leak paths
Rotary Distributor Pump & Nozzle	same as Unit Injectors	Three leak paths

The leakage effects are highly dependent upon the physical design of the injection equipment, the radial clearance between barrel and plunger, plunger diameter, and length of seal between barrel and plunger. For some given applications injection pump designers alter seal length (**7**) to accommodate lower viscosity fuels. Viscosity also affects the injector spray jet break-up length and penetration rate, although the quantitative effects are injection system design-dependent (**8**).

Viscosity has another effect in fuel-lubricated injection pumps that use the fuel to provide the hydrodynamic film in a journal type bearing. Lowering fuel viscosity decreases hydrodynamic film thickness. Studies (**9**) have shown that robustness of injection pump design can alleviate any concerns about JP-8 versus DL-2 hydrodynamic film strength.

G. Fuel Lubricity Impacts on Diesel Engines

Lubricity indicates the boundary lubricating quality of a fuel oil. Boundary lubrication is the molecular strength of a fluid to keep sliding and rolling contacts separated and is primarily a function of chemical composition. Fuel lubricity can impact fuel injection system performance by increasing critical injection pump clearances due to wear. Increased injection pump clearances may result in increased leakage rates and delayed pressure development. Highly refined fuels such as JP-8 have lower lubricity than DL-2 due to a reduction of polar species in the refining process. The addition of formulated diesel engine oil to JP-8 has been shown to lower fuel lubricity, while other POL materials may improve JP-8 fuel lubricity (**9**) [5]; however, the impact on performance with continuous use remains unknown. The lubricity of JP-8 is known to improve with the addition of corrosion inhibitors, which interrupts the corrosive wear process (**10**). The ASTM D5001 Ball-on-Cylinder Lubricity Evaluator (BOCLE) test specified for determining lubricity of aviation fuels is characterized by a lightly loaded contact, and a corrosive wear mechanism. The Army Scuffing Load

[5] Measured utilizing American Society for Testing and Materials (ASTM) D5001 Ball-on-Cylinder Lubricity Evaluator (BOCLE) procedure.

Wear Test (SLWT), a modification of the BOCLE procedure, was developed to evaluate the effect of fuel lubricity in diesel equipment with more highly loaded contacts and a scuffing wear mechanism (**11**). JP-8 fuels that can be characterized as low lubricity by the SLWT (loads under 2.2 kg) can be improved to acceptable levels by ten times over treatment of the MIL-I-25017 corrosion inhibitor additive (**12**). Addition of engine oils can increase SLWT loads, but at concentrations two orders of magnitude higher than the corrosion inhibitor additive (**13**). The corrosion inhibitor additive in JP-8 reduces wear in both lightly- and highly-loaded contacts, whereas engine oil addition to JP-8 reduces wear in highly-loaded contacts only.

H. Fuel Impacts on Engine Durability

Durability of fuel injection equipment is primarily affected by fuel lubricity through increased wear of the boundary lubricated contacts in fuel-lubricated injection systems. Engine performance degradation resulting from alterations of both fuel delivery and injection timing can occur in commercial quality injection systems due to low fuel lubricity and low viscosity-induced wear (**9**,**14**).

Injection equipment installed with hardened "arctic" components designed for low lubricity and low viscosity fuels has demonstrated improved durability with respect to commercial components with JP-8 fuel (**9**,**15**). Although the durability of equipment with JP-8 is reduced somewhat from DL-2 in research studies, there has not been any evidence of inadequate durability or catastrophic wear in fuel injection equipment with JP-8 in field studies (**16**,**17**,**18**).

Dynamometer testing indicates diesel engine durability is similar, or slightly improved, due to the use of JP-8 instead of DL-2. Lower rates of lubricant oxidation, fewer wear metals, less top ring wear, lower combustion chamber deposits, and slight reductions of injector deposits were seen on several engine types (**14**).

I. Fuel Impacts on Hot-Starting and Hot-Idling

During a soak-back period, the fuel injection pump and the fuel it contains increase in temperature. This occurs partially due to radiative heating from hot engine pans, the absence of cooling air flow across the engine, and the lack of fuel flow to cool the injection system. As the fuel injection pump is heated, the fuel contained within is reduced in viscosity as a function of the pump and fuel temperature. An engine will not start when the leakage in the high-pressure head does not allow enough fuel to be delivered at cranking speeds. A combination of hot, low viscosity fuel, increased clearances due to wear, and increased time due to low cranking speeds may result in increased fuel leakage past the pumping plunger(s), reducing fuel delivery and retarding injection timing. Hot idle difficulties may also appear with lower viscosity fuels, due to insufficient fuel delivery at idle speeds. Hot starting and hot idle performance with lower viscosity fuels such as JP-8 are potential problems, especially in fuel injection systems which have multiple leak paths, such as rotary fuel injection systems. A systematic study of the combined effects of fuel viscosity and pump component wear on hot start and hot idle performance with JP-8 and DL-2 fuels has been proposed (**19**).

J. Power and Performance

The effect of JP-8 use instead of DL-2 on engine power and automotive performance is primarily seen at conditions such as full-rack acceleration, towing, and vehicle recovery. (The diesel engine rack directly varies the metered fuel quantity for controlling engine power output.) The first order approximation of the full-rack power debit with JP-8 would be the fuel volumetric heating value deviation from DL-2 [6]. Results show power deviations can also be highly engine and injection system-dependent. Engines with higher injection pressures show the greatest power deviations at full-rack (**14**). Thus, newer low emission engines, with high injection pressures for improved fuel/air mixing, may be more sensitive to power loss with JP-8. Engines that use pressure-time metering of fuel show little power deviation with JP-8. Automotive performance evaluations with vehicles on JP-8 have verified power dependency on injection system configurations (**20**,**21**,**22**). Because vehicles rarely operate at flail-rack, the power debit with JP-8 is not seen to impact overall vehicle performance (**17**).

K. Fuel Consumption

At typical road and mission loads, the vehicle operator gives more rack with JP-8 than DL-2 to meet the mission performance goals. The net effect of partial rack performance with JP-8 is an increase in engine and vehicle fuel consumption relative to DL-2. The increase in engine and vehicle fuel consumption with JP-8 is equivalent to the deviation of the fuel volumetric heating value from DL-2 (**14**,**20**,**21**,**22**). Experience has shown that the bulk fuel consumption will be contingent on vehicle and equipment mix and usage, and direct comparison of average vehicle fuel consumption between DF-2 and JP-8 will not reveal any statistically significant difference (**23**).

L. Smoke Generation

Selected armored vehicles equipped with Vehicle Engine Exhaust Smoke Systems (VEESS), which draw from the fuel cell, cannot produce an obscuring or persistent smoke when using JP-8. The superheated JP-8 vapor from the exhaust system cannot cool, condense, and nucleate to form a fog before it is dissipated (**24**,**25**).

M. Hot and Cold Weather Operations

Hot weather performance of ground vehicles utilizing JP-8 or DL-2 will change due to the strong inverse relationship of fuel viscosity to fuel temperature. Typical distillate hydrocarbon fuel have the same viscosity index (viscosity-temperature slope). Durability tests for 10,000 miles in hot climates, with 145° to 163°F fuel inlet temperatures (with respective 1.08 to 0.97 cSt JP-8 fuel viscosity), have revealed no impact on vehicle performance or fuel-lubricated rotary-type fuel injection pump wear with JP-8 (**16**). Evaluations utilizing JET A fuel (JP-8 without corrosion inhibitors) were performed at a continuous 195°F fuel inlet temperature using the 400-hour NATO durability cycle on five engines (**26**). Some injection system performance impact was seen at 195°F on JET A, but injection pump performance criteria were met at 110° to 115°F calibration stand temperatures. Other fuel injection systems showed no performance impact due to the 195°F JET A operation. JET A/A-1 has been shown to have substantially lower lubricity than JP-8 (**9**). Vehicle hot starting remains to be evaluated -- whether at elevated fuel temperatures the fuel injection equipment critical viscosity requirements are compromised while utilizing JP-8, and not compromised while utilizing DL-2.

The use of JP-8 in cold weather results in similar unaided cold start response with respect to DL-1 and DL-2 (**27**). The lower viscosity and higher volatility of JP-8 would result in better fuel and air

[6] Power debits also occurred when using the M1 fuel mix and winterized diesel fuel because of their lower volumetric heating value with respect to diesel fuel, but these losses were often not noted by the user, or had no mission impact.

mixing during cold starts. The better fuel and air mixing with JP-8 would offset the increased ignition delay due to the slightly lower cetane number than DL- 1 and DL-2. The volatility of JP-8 may improve startability in a burner-type manifold heater-equipped engine. Engines designed to operate on 45 to 50 cetane number fuels, high swirl combustion chambers (high convective heat transfer), may have difficulties starting on JP-8. The lower viscosity and lower cloud point of JP-8 reduce injector filling difficulties (**28**) and spray atomization degradation that may result from viscous and waxed diesel fuel in cold climates.

IV. U.S. Army JP-8 Field Experience

A. U.S.

1. JP-8 The Single Fuel Forward, Information Compendium (**29**)

The information compendium is updated periodically to include new and relevant information concerning aviation kerosene turbine fuel with emphasis on its use in ground vehicles and equipment. The JP-8 information compendium contains information on fuel types, commonly asked questions about JP-8 in diesel engines, and various fact sheets on JP-8. Also included are recommendations on fuel conversions, lubricity guidelines, component service bulletins, and field expedient additive blending guides. The compendium includes the abstracts of fifty-two relevant reports and publications concerning the use of JP-8 in ground vehicles and equipment.

2. 10,000-Mile JP-8 Fuel Test of 6.2L Diesel Engine in M1028 CUCV Vehicles (**16**)

From the vehicle performance there was no indication of wear in any engine component that resulted in power loss. The drawbar test results at the start of test and end of test were nearly identical and within the power range anticipated for the engines. Likewise, the 1,000-mile acceleration/deceleration tests and the vehicle top speed attained on the high speed track showed no performance deterioration. Vehicle fuel consumption stabilized quickly and improved slightly during the testing; the overall difference in fuel consumption between fuels was 7 percent fewer miles/gallon with JP-8. The JP-8 fuel pumps were calibrated on the high side to compensate for the potential 6 percent power loss due to the lower heating value of the JP-8 fuel.

3. Ft. Bliss JP-8 Demonstration (**17**,**18**,**23**)

A JP-8 demonstration program was conducted at Ft. Bliss, TX, during the period October 1988 through July 1990 involving more than 2,800 pieces of diesel engine-powered vehicles and equipment that comprised the combat, tactical, administrative, and Transportation Motor Pool fleets. Approximately 4,700,000 gallons of JP-8 fuel were dispensed to units at Ft. Bliss and Ft. Irwin, CA, (National Training Center) during the demonstration. The program verified the use of JP-8 fuel in diesel engine-powered vehicles and equipment without any catastrophic failures attributable to JP-8 usage and with widespread acceptance from the command, maintenance, and user personnel. The conclusions that follow resulted from the demonstration program.

There were no major statistical differences in fuel procurement costs, vehicle and equipment fuel consumption, AOAP-directed oil changes, fuel-wetted component replacements, or wear metals with JP-8 fuel usage. There was no impact on cost, performance, or mission that was judged to be the result of using JP-8 fuel. Based on the demonstration program results, Ft. Bliss requested to remain on JP-8 fuel and has been using JP-8 since that time.

4. CONUS/OCONUS Conversion

The following CONUS organizations have successfully convened to the use of JP-8 as the single fuel forward for their ground vehicles and equipment:

USA, Ft. Bliss, TX	USA, Ft. Hood, TX	USA, Ft. Irwin, CA
USA, Ft. Riley, KS	USA, Ft. Campbell, KY	USA, Ft. Carson, CO
USA, Ft. Sill, OK	USA, Ft. Huachuca, AZ	USA, Ft. Lewis, WA
USA, Ft. McCoy, WI	USA, Ft. Drum, NY	USA, Ft. Eustis, VA
USA, Ft. Stewart, GA	USA, Camp Shelby, MS	USA, Ft. Indiantown Gap, PA
USA, Ft. Bragg, NC	USA, Ft. Hunter-Ligget, CA	USA, Ft. Polk, LA
USA, Camp Guernsey, WY	USMC, Camp Pendelton, CA (JP-5)	

The following OCONUS organizations have convened to the single fuel forward for their ground vehicles and equipment:

PACOM	EUCOM	CENTCOM	SOUTHCOM

The number of diesel engine-powered vehicles and equipment utilizing JP-8 worldwide represented by the aforementioned units is substantial. To date, the only CONUS or OCONUS organizations that have relayed operational issues due to the utilization of JP-8 are the USAF-Korea and more recently USAF-Europe. Complaints issued dealt primarily with commercial vehicles operating on JP-8, which use fuel-lubricated rotary fuel injection pumps from three fuel injection system manufacturers.

A survey was taken of the USA activities within CONUS that use commercial construction and materials handling equipment for operability issues with JP-8 (**30**). The Army commercial construction and materials handling equipment utilize rotary fuel injection pumps similar to those used by the USAF equipment. The responses from the survey indicated that the USA is not having any operational problems with their commercial construction and materials handling equipment while utilizing JP-8.

B. NATO Compendium (**31**)

The U.S. Army is the DoD representative on the NATO Pipeline Committee Working Group No. 4, Ground Fuels Working Party. A joint effort of this group is to maintain a catalogue of the nations' test results. A compendium of all engine or component testing and field trials being conducted within the NATO countries that involve use of JP-8 has been developed. The compendium of test results is updated semiannually by the fourteen member nations of NATO. An area of interest to the NATO nations has been the effect of JP-8 on light-duty, rotary fuel injection pumps.

C. Single Fuel Forward

The Single Fuel Forward concept has been used by the DoD for military and peacekeeping missions since 1988. The actions include Panama (Operation Just Cause), Saudi Arabia (Operation Desert Shield/Storm), Turkey (Operation Provide Comfort), Somalia, Haiti, and Bosnia (Operation Joint Endeavor).

1. Panama, Operation Just Cause

The Single Fuel Concept in Panama during Operation Just Cause utilized JP-5 fuel because of the large Navy requirement in that area. Any operational difficulties with JP-5 were determined to be caused by dirt and water contamination of vehicle fuel systems.

2. Saudi Arabia, Operation Desert Shield/Storm (**32**)

A data collection survey was taken on units that used kerosene-based JET A-1 during Operation Desert Shield/Storm. Results showed JET A-1 to be a suitable combat fuel for ground vehicles/equipment for units that used it throughout the conflict. Units that had been utilizing kerosene-based fuels (such as JP-8 or JP-5) before the use of JET A-1, such as those at Ft. Bliss, TX, had significantly fewer problems than units that switched from diesel fuel while in the theatre. There was insufficient evidence to suggest that JET A-1 was a major factor in the fuel injection pump failure rates during the initial buildup. Results from an inspection of fuel injection pumps suggested most of the failures were related to dirt, water, flex-ring failures, unauthorized maintenance practices, improper rebuilds, and cumulative wear. The failure rates were also caused in part by the drastically increased equipment usage, with equipment attaining enough operating hours to exceed the mean time before failure.

Several generator set fuel injection pumps were evaluated during Operation Desert Shield for the cause of these failures. Results indicated the failures were not due to JET A-1 use because several pumps contained foreign material, solid particles, relatively mild wear on critical components, some corrosion, and mismatches between metering valve and metering valve bore. (**33**) Wear analysis of diesel engine fuel injection pumps revealed that the use of JET A-1 does increase wear, many failure mechanisms other than fuel lubricity were prevalent, and pumps with improved metallurgy were less sensitive to fuel lubricity. (**34**)

3. Turkey, Operation Provide Comfort; Somalia; Bosnia, Operation Joint Endeavor

The single fuel used in Turkey during Operation Provide Comfort and in Bosnia during Operation Joint Endeavor was JP-8. The single fuel utilized in the Somalian peacekeeping mission was JP-5. To date, no operational issues concerning use of JP-8 or JP-5 in ground vehicles and equipment were reported.

4. Haiti

The single fuel used in the Haitian peacekeeping mission was JP-5. The only operational issues reported were by contractors operating commercial vehicles utilizing GM 6.5L diesel engines equipped with rotary fuel injection pumps. The main operational issue dealt with hot starting, which the fuel injection pump manufacturer acknowledged with Stanadyne Service Bulletin No. 484R4, which issued a replacement hydraulic head and rotor. Operational issues with military vehicles have not been reported.

V. U.S. Air Force JP-8 Field Experience

A. Korea

United States Air Force units in Korea, operating on JP-8 type fuel, have been experiencing vehicle performance degradation in the mission-critical equipment that use commercial quality rotary fuel injection pumps. A common complaint has been vehicle hot restarting. Three types of rotary fuel injection pumps from three separate manufacturers have been reported as experiencing performance degradations. The common denominator between these pumps is that rotary fuel injection pumps utilize the fuel to lubricate all the internal components. Typically, these pumps are designed for use in commercial service to use fuel with the viscosity and lubricity characteristics of diesel fuel. The effect on pump durability and wear of utilizing a JP-8 type fuel in these three unique commercial rotary fuel injection pumps, and the subsequent impact on hot restarting, need to be understood in order to develop a technical solution.

The difficulties identified with the use of JP-8 in USAF ground vehicles and equipment have resulted in a permanent waiver for the Air Force to use diesel fuel in Korea. (**35**)

B. USAFE

1. HQ 3AF Fuels, RAF Mildenhall (36)

The 3AF undertook a DF-2 to JP-8 conversion program with a goal to operate all vehicles on JP-8. Many growing pains regarding JP-8 as a vehicle fuel ended with the conclusion of a successful JP-8 test. The test showed JP-8 did not harm diesel engines, although some performance degradation was present in certain UK-manufactured vehicles.

The degraded vehicle performance was unacceptable. Consequently, the 3AF enlisted the help of the U.S. Army Belvoir Research and Development and Engineering Center. The Army team met with vehicle manufacturers and base vehicle maintenance personnel to provide advice, problem resolution, recommendations, and guidelines for the selection of diesel engines that will respond well on JP-8 for fixture UK vehicle acquisition.

2. HQ USAFEILGTV (**37**)

A Stanadyne fuel injection pump from the USAFE was inspected due to a no-start complaint. Upon inspection of the pump, it was determined the rotor had seized in the hydraulic head and the pump drive had sheared. Inspection revealed no evidence of dirt or moisture contamination. From the condition of the internal pump components, there was nothing apparent which would result in hard starting or head and rotor seizure within the pump. Inspections showed the rotor seizure may have been caused by either water in the fuel or spraying down of the injection pump with water. Inconsistent with water in the fuel mechanism is the lack of corrosion in the remainder of the pump. The spraying of the pump with water usually results in differential contraction of the hydraulic head and rotor, causing metal-to-metal contact at the transfer pump end of the rotor. In this pump, the point of seizure was inconsistent with the location usually seen with differential contraction, the point of seizure being more consistent with the location for water in the fuel. The visual wear in the USAFE injection pump appeared typical for JP-8, without any indication that wear on any of the components would have led to the pump rotor seizure.

VI. The Future with JP-8

A. Future Emission Regulations

The present issues with JP-8 are mainly due to use in vehicles/equipment with engines designed for DL-2 fuel properties, and somewhat lenient emission standards. Diesel exhaust emission regulations are set for 1998, and the regulations for 2004 are already being developed. The most likely scenario for the 2004 heavy-duty diesel emission regulations will be further reduction in NOx emissions to 2.0 grams/blip-hr (presently 5.0 gr./bhp-hr), with a greater emphasis on engine emission durability. The fuel/engine changes that will be required to meet the fixture emission standards may provide a benefit for the utilization of JP-8 in fixture ground vehicles and equipment.

1. Fuel Specifications

The lowering of NOx emissions has an inverse effect on Particulate Matter (PM) emissions, known as the NOx-PM tradeoff. To lower NOx and maintain present PM emission levels, fuel specifications will most likely include further reductions in the fuel sulfur level, 90 percent distillation temperature, and a further reduction in fuel aromatic content. Sulfur may eventually be reduced to the Swedish Class 1 (0.001 wt. %) and Class 2 (0.005 wt. %) fuel levels from the present EPA level (0.05 wt. %). The reduction in fuel sulfur, distillation temperature, and aromatic content will be accomplished by increased levels of hydro treating and other refining processes. This increased level of refinement will result in low lubricity fuels, as was seen with the Swedish low sulfur fuels.

2. Engine Requirements

Diesel fuel injection systems will become more robust to maintain emission warranties with low lubricity diesel fuels. Improved fuel injection system robustness would be beneficial for diesel engines that use JP-8. The technology that may be developed for future low lubricity diesel fuel use may also be applied to older equipment that uses JP-8, to extend its service life.

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VIII. Appendix

What is JP-8, in contrast to other military and commercial fuels?

All general purpose fuels are distilled from crude oil to meet physical property requirements in military or commercial specifications. Attachment A lists several fuel specifications relevant to this discussion. These specifications define acceptable ranges of important properties such as the boiling range, viscosity, or cetane number. These requirements are sufficiently broad that often there is overlap between requirements, and variation between fuels that meet a specification. Sometimes, the overlap can be exploited to produce a fuel that will meet more than a single specification.

A. Chemical and Physical Properties

Figure A-1 illustrates the distillation range of several fuels of interest, and highlights the similarity between the fuels meeting the various specifications. As this figure implies, JP-8 has physical and chemical properties that are similar to JP-5, JET-A, and JET A-1. Table A-1 compares average values of fuels sold under the various fuel specifications, as reported in several fuel surveys.

Several differences between JP-8 and the diesel fuels in Table A-1 are of particular interest when JP-8 is considered as an alternative for diesel engines. The density, viscosity, and net heat of combustion alter power generation and fuel consumption in diesel engines. The cloud point and viscosity affect cold starting, cold operability of both diesel and gas turbine engines.

B. Additives

MIL-DTL-83133 grade JP-8 is a kerosene-based fuel containing three mandatory fuel additives that distinguish it from commercial grade JET A and A-1. These additives include a fuel system icing inhibitor (MIL-DTL-85470), a static dissipator additive, and a corrosion inhibitor (MIL-PRF-25107). The fuel system icing inhibitor has a secondary effect of inhibiting the growth of microbiological organisms in JP-8.

C. Lubricity, Cleanliness and Other Uncommon Properties

The corrosion inhibitor also modifies the lubricity characteristics of JP-8. The specification for corrosion inhibitors, MIL-PRF-25017, establishes a maximum allowable ASTM D5001 BOCLE wear scar diameter of 0.65 mm for JP-8. Because the intended use of JP-8 is for aircraft, the cleanliness requirement included in the MIL-DTL-83133 specification is cleaner than DL-2. Other specification properties of JP-8 not commonly specified for DL-2 include fuel thermal stability and fuel hydrogen content.

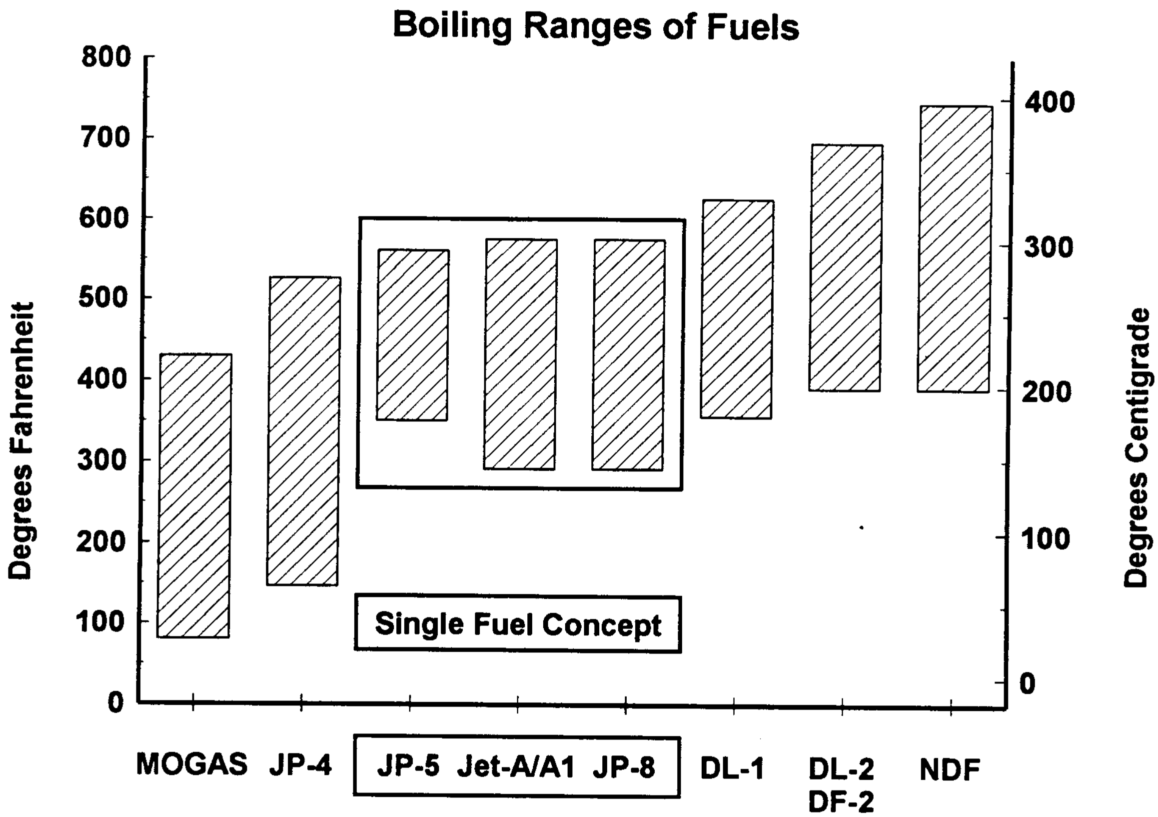


Figure A-1. Boiling Ranges of Common Motor Fuels

Table A-1. Selected Typical Fuel Properties

	JP-4	JP-5	JP-8	DL-1	DL-2
Gravity, °API	55.3	41.1	45.6	42.3	34.2
Density, lb/gal	6.306	6.826	6.652	6.779	7.111
Kinematic Viscosity at 40°C, cSt	0.56	1.5	1.2	1.6	2.8
Cetane Number	23	42	45	44	47
Cloud Point, °C	-63	-46	-47	-41	-12
Net Heat of Combustion, Btu/gal	118,124	125,270	123,069	125,960	131,207
Percent Btu/gal change from DL-2	-10.0	-4.5	-6.2	-4.0	0

D. Fuel Property Variation Impacts

The following physical properties that differ between JP-8 and DL-2 impact the fuel injection process, and ultimately the maximum power available from a diesel engine.

Density - Diesel fuel injection systems meter fuel by the volume of the effective metering stroke.

Fuel density influences the injection process by altering the mass of fuel delivered during the effective metering and injection stroke. For the same effective metering and injection stroke, less mass of JP-8 fuel than DL-2 would be injected, but the injection pressure would be similar because all hydrocarbon fuels have virtually the same bulk modulus. Bulk modulus is the fuel modulus of elasticity, which is the inverse of the fuel compressibility.

Viscosity - Changes in fuel viscosity change the fuel injection process, despite how this physical property of the fuel is varied. Most of the injection changes result from differences in the internal leakage from the high pressure regions of the pump and injection nozzle. The internal leakage from a fuel injection pump barrel and plunger assembly can be characterized as: [7]

$$Q = \frac{C\, b^3\, D\, \Delta p}{\mu\, L} \qquad (1)$$

where:
Q = leak rate, in^3/sec
C = constant, 4.51E-05
b = radial clearance, in 0.001 inches
D = plunger diameter, inches
L = length of seal, inches
Δp = pressure differential across seal length, psi
p = absolute viscosity of fuel poise

[7] Paul G. Burman and Frank DeLuca, "Fuel Injection and Controls for Internal Combustion Engines," Copyright 1962 by Paul G. Burman & Frank DeLuca, USA.

The leakage is dependent upon the physical dimensions of the injection equipment (the radial clearance, plunger diameter, and length of seal) and the fuel viscosity. The radial clearance used in fuel injection systems is constrained by manufacturing capabilities, and cannot be reduced from present practice. The plunger diameter and injection pressure are generally determined by the injection system application. Plunger diameter determines injected fuel quantity. Injection pressure is specified by the engine manufacturer for controlling fuel/air mixing and spray penetration and tend to be increasing for reducing exhaust emissions. For low viscosity fuel use, the length of seal between the barrel and plunger is the only physical dimension that practically can be altered to reduce fuel leakage.

Equation 1 multiplied by fuel density reflects the fuel mass leakage rate in terms of fuel kinematic viscosity. Holding the physical dimensions and pressure differential constant in equation 1, the relative leak rates for the fuels in Table A-1 can be evaluated. Table A-2 estimates the fuel mass variations relative to DL-2 due to the fuel density effect on metered quantity, the fuel viscosity effect on leak rates, and the combination of density and viscosity effects on injected fuel mass.

Table A-2. Fuel Injection System Mass Variations Due to Viscosity and Density

	JP-4	JP-5	JP-8	DL-1	DL-2
mass fuel metered relative to DL-2	0.8868	0.9959	0.9359	0.9533	1.0
mass leak rate relative to DL-2	5.00	1.87	2.33	1.75	1.0
mass fuel injected relative to DL-2	0.8827	0.9590	0.9341	0.9525	1.0†

† assuming leak rates with DL-2 are on the order of 0.1-percent of injected fuel quantity (Burman and DeLuca).

Attachment A

Designations and Explanations of Fuel Types [8]

Designation	NATO Code Number	Defining Specification	Description
JP-4	F-40	ASTM D1655	Volatile turbine fuel containing more than 50 percent gasoline fractions.
JP-5	F-44	MIL-DTL-5624	Reduced flash point kerosene-based turbine fuel, intended for Navy shipboard use.
JP-8	F-34	MIL-DTL-83133	Kerosene-based turbine fuel identical to JET A-1 except JP-8 mandates three fuel additives that are optional in JET A-1
JET A-1	F-35	ASTM D 1655	Commercial kerosene turbine fuel used worldwide by airlines.
JET A	none	ASTM D 1655	Industry standard variant of JET A-1, with slightly higher freeze point (-40°C vs. -47°C). Used only within U.S.
DF-2	F-54	A-A-52557	Commercial off-highway diesel fuel; military diesel fuel.
DL-2	none	A-A-52557 and ASTM D 975	Commercial low sulfur diesel fuel.
DL-1	none	A-A-52557 and ASTM D 975	Commercial low sulfur, low cloud point diesel fuel.
NDF	F-76	MIL-F-16884	Naval Distillate Fuel

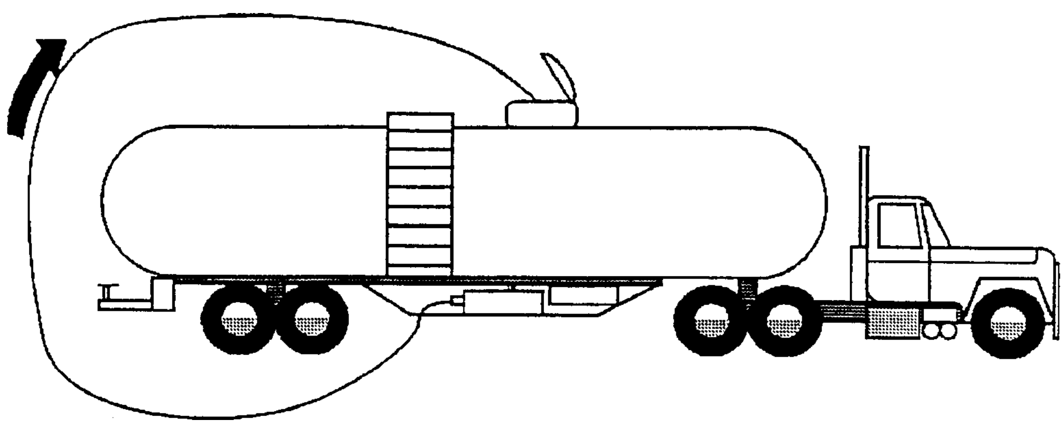
[8] Abstracted from "Fuel Users Guide - 1996" produced by the U.S. Army Tank-Automotive RD&E Center, Mobility Tech Center - Belvoir, AMSTA-RBF, Ft. Belvoir VA.

Attachment B

ABBREVIATIONS AND ACRONYMS USED

AOAP	Army Oil Analysis Program
CENTCOM	U.S. Central Command
CONUS	Continental United States
CUCV	Commercial Utility Cargo Vehicle
EPA	Environmental Protection Agency
EUCOM	U.S. European Command
GFWP	Ground Fuels Working Party
GM	General Motors
HMMWV	High Mobility Multipurpose Wheeled Vehicle
K	Kinematic
OCONUS	Outside Continental United States
PACOM	U.S. Pacific Command
POL	Petroleum, Oils and Lubricants
SOUTHCOM	U.S. Southern Command
STANAG	Standardization Agreement
TACOM	U.S. Army Tank-automotive and Armaments Command
TARDEC	U.S. Army Tank-Automotive Research, Development and Engineering Center
TFLRF	U.S. Army TARDEC Fuels and Lubricants Research Facility at Southwest Research Institute
UK	United Kingdom
USAFE	U.S. Air Force Europe

GUIDE FOR FIELD BLENDING OF ADDITIVES OR FOR WINTERIZING GROUND FUELS



AMSTA-TR-D/210
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This Guide provides the procedures to be followed for the field blending of additives into ground fuels, and for the winterization of diesel fuels. **Section I** covers the field blending of additives whereas **Section II** covers the field blending of fuels for winterization (e.g., kerosene blending).

I.-- Field Blending of Additives

I.A -- Introduction.

The Army has maintained a long-standing policy of recommending against any introducing of additives into fuels in the field and prefer to only handle fuels that have been fully additive treated (i.e., finished fuels). There are however some exceptions that necessitate the introducing of additives into fuels in a field environment. This field addition of additives is however the exception and not the rule.

This Guide provides general guidance for the field addition of additives to all ground military fuels by means of batch blending. Such blending of fuels is considered a **field-expedient method** and is used only when (1) additive injection equipment is not available, and (2) the particular situation warrants this field expedient fix. Additive injection equipment includes the Hammonds Portable Multi-Additive Injector, and the Army's experimental Fuel Filtration Additive Unit (FAU). The decision to add fuel additives in the field should be based on feedback from the field and/or the results of laboratory tests. Fuels treated by batch blending should only be used in *ground vehicles and equipment*. Distillate fuels (e.g., diesel fuel) and kerosene-based fuels (e.g., JP-5, JP-8, ASTM JET A, and JET A-1) are the only fuel types that should be considered for field-blending. Gasoline (i.e., MOGAS and AVGAS) and other naphtha-based fuels (e.g., JP-4 and JET B) should *never* be field blended.

Examples of those situations where field addition of additives to fuel, hereafter referred to as batch blending, are warranted include:

- Upgrading JET A-1 to JP-8 by blending in the three military additives; namely, the Corrosion Inhibitor/Lubricity Improver (MIL-PRF-25017), the Fuel System Icing Inhibitor (MIL-DTL-85470), and the Static Dissipator Additive.
- Addition of the Stabilizer Additive (MIL-S-53021) to diesel fuel in order to enhance its storage capabilities and/or to eliminate the infestation cause by the presence of microorganisms (i.e., microbiological growth formations).
- Addition of Corrosion Inhibitor/Lubricity Improver (MIL-PRF-25017) to diesel fuel or ground turbine fuels in order to its enhance lubricity.

Batch blending of fuels is best accomplished in tank vehicles, tank semi-trailers, and above-ground tanks equipped with a bottom discharge. Batch blending is also possible in underground tanks using special equipment and procedures. However, blending is *not* possible in collapsible (e.g., pillow) tanks, and is generally impractical in 500-gallon collapsible drums, vehicle/equipment fuel tanks, or in fuel cells.

Batch blending is best performed by preparing a premix of the additive with fuel, and then adding the premix *ahead* of the bulk fuel during loading operations. The premix will dilute the additive and facilitate mixing. In general, additives should not be combined together in a premix as some additive will interact with each other if present in a concentrated solution.

The most effective is way to accomplish the mixing of additive with fuel is to re-circulate within the tank using the on-board or auxiliary pump. A less effective way to accomplish this is by movement of the tank vehicle over a rough terrain. The least effective way is by addition of the premix on top of the bulk fuel. The mixing times should generally be doubled for the blending of fuel and additives using this method.

A summary of the different additives covered in this Field Blending Guide, their purpose, and the section in this Guide where they are addressed are shown in Table 1.

Table 1.

Additive	Purpose	Sections found in
Fuel System Icing Inhibitor (FSII) (MIL-DTL-85470)	To prevent freezing of separated water in fuel; one of the three mandatory additives in JP-8	**I.C**
Corrosion Inhibitor/Lubricity Improver (MIL-PRF-25017)	To improve the corrosion resistance of the fuel; one of the three mandatory additives in JP-8	**I.D, I.E**
Paradyne 655	To improve the lubricity of ground fuels	**I.F**
Stabilizer Additive, Diesel Fuel (MIL-S-53021)	To retard or prevent the formation of fuel deterioration products in ground fuels; to eliminate the presence of any microbiological growth in ground fuels	**I.G**

I.B -- General Precautions.

While most fuel additives are not generally highly toxic, protective gloves and goggles should be worn. Although a respirator is not required, its use is recommended. Skin contact with any of the additives should be avoided. In the event of an unprotected contact, the exposed area should be thoroughly washed with soap and water. In the event of eye contact, immediately wash the eye with large quantities of water; continue the wash for at least 15 minutes, and obtain medical help as soon as possible. When the additive is diluted with fuel, the health hazards are significantly reduced. Additional information on health, fire and toxicological hazards will be found in the appropriate Material Safety Data Sheet (MSDS) found with the additive container.

Nozzles and hoses placed on top of fuel tank vehicles should be firmly secured. Metal components should be grounded to the tank chassis. Filter/separators should not be used during any fuel re-circulation process as their use can significantly increase the build-up of static electricity. All personnel should stay off the top of tank vehicles during pumping, re-circulating, or refueling.

I.C -- Addition of Fuel System Icing Inhibitor (FSII) to Ground Turbine or Diesel Fuel.

FSII is added to fuel to prevent freezing of separated water. This additive is soluble in both fuel and water and, in the presence of separated water, will migrate from the fuel to the water layer/phase. In general, it is used in cold climates where subfreezing ambient temperatures are expected.

I.C.1 -- Steps to Follow:

a -- Obtain sufficient FSII meeting MIL-DTL-85470 (di-ethylene glycol monomethyl ether) using the National Stock Numbers (NSNs) as shown in Table 2.

Table 2.

Nomenclature	Container	NSN
Fuel System Icing Inhibitor, MIL-DTL-85470	Five gallon can	6850-01-057-6427
	Fifty-five gallon drum	6850-01-089-5541

b -- Check the fuel before addition for existing FSII by using the B-2 Test Kit or other suitable laboratory method. Do not add additional FSII if it is already present in the fuel. Recommended concentration of FSII in fuel is 0.10 to 0.15 volume percent for JP-5, JP-8, JET A, and JET A-1. Diesel fuel can tolerate up to 0.25 volume percent FSII (or even greater amounts) if needed.

c -- Prepare the premix by combining fifty (50) percent FSII, as received, with fuel in a suitable container such as a Jerri can or one-gallon jug. Mix thoroughly by shaking the container for at least one or two minutes. The premix is now ready for the batch blending process.

I.D -- Addition of Prescribed Levels of Corrosion Inhibitor/Lubricity Improver (MIL-PRF-25017) to Ground Turbine or Diesel Fuel.

Corrosion Inhibitor/Lubricity Improver can be added at prescribed levels to JET A, JET A-1, or diesel fuel to improve the corrosion resistance of the fuel.

I.D.1 -- Steps to Follow:

a -- Obtain sufficient Corrosion Inhibitor/Lubricity Improver using the National Stock Numbers shown in Table 3 or directly from a vendor listed in a current edition of the Air Force Qualified Products List, QPL-25017.

Table 3.

Nomenclature	Container	NSN
Corrosion Inhibitor/ Lubricity Improver	One gallon can	6850-01-180-1074
	Fifty five gallon drum	6850-00-292-9780

The recommended concentration of the Corrosion Inhibitor/Lubricity Improver for conventional use varies by manufacturer/vendor as defined in QPL-25017. Use the minimum effective concentration (mec) and assume g/m^3 is equivalent to parts per million (ppm) by volume.

b -- Prepare the premix by combining fifty (50) percent Corrosion Inhibitor/Lubricity Improver, as received, with fuel in a suitable container such as a Jerri can or one-liter bottle. Shake container for one or two minutes in order to mix thoroughly. The premix is now ready for the batch blending process.

I.E -- Addition of Corrosion Inhibitor/Lubricity Improver (MIL-PRF-25017) to Enhance Lubricity of Ground Fuels.

Higher levels of Corrosion Inhibitor/Lubricity Improver may be used to enhance the lubricity of ground fuels that have been found to be deficient in lubricity as determined by either the ASTM D6078 (Scuffing Load BOCLE Test) or ASTM D6079 (High Frequency Reciprocating Rig. Test) procedures.

I.E.1 -- Steps to Follow:

a -- Obtain sufficient Corrosion Inhibitor/Lubricity Improver from the National Stock Numbers shown in Table 3 or from a vendor listed in the Air Force QPL-25017. Recommended concentration for <u>this</u> application is 250 parts per million (ppm) by volume.

b -- Prepare the premix by combining fifty (50) percent Corrosion Inhibitor/Lubricity Improver, as received, with fuel in a suitable container such as a Jerri can or one-liter bottle. Shake container for one or two minutes in order to mix thoroughly. The premix is now ready for the batch blending process.

I.F -- Addition of Paradyne 655 Additive to Optimize Lubricity of Ground Fuels.

The Paradyne 655 additive manufactured by Exxon Chemical Company has been found to be an excellent lubricity improver. It can provide the highest degree of wear protection. It should be utilized when severe wear problems persist, or when the fuel has been tested and found to have very low lubricity.

WARNING: The Paradyne 655 additive should not be blended in fuel when the ambient temperature is expected to be below -20^{o}C (-4^{o}F).

I.F.1 -- Steps to Follow:

a – The Paradyne 655 additive can be procured from one of the following sources:

Exxon Chemical Co. Paramins Division P.O. Box 719 Linden, NJ 07036 Attn: Customer Service Center (800) 654-1233	Exxon Chemical Ltd Paramins Business Center P.O. Box 255 Abingdon Oxfordshire OX13 6TT United Kingdom (44) 1235 545700
Exxon Chemical Japan Ltd. TBS Kaikan Bldg 3-3 Akasaka 5-Chome Minato-ku Tokyo 107, Japan Attn: A. Kato-Paramins (03) 3585 9320	Exxon Chemical Singapore Pte Ltd 14 Science Park Drive Unit 02-01 Singapore 118226 Attn: S. Sim-Paramins (65) 779 1116

The recommended concentration is 80 parts per million (ppm) by volume, but the concentration can be increased to 200 ppm by volume if necessary.

b -- Prepare the premix by combining fifty (50) percent Paradyne 655, as received, with fuel in a suitable container such as a Jerri can or one-liter bottle. Shake container for one or two minutes in order to mix thoroughly. The premix is now ready for the batch blending process.

I.G -- Addition of Stabilizer Additive, Diesel Fuel, MIL-S-53021, to Ground Turbine or Diesel Fuels.

The Diesel Fuel Stabilizer Additive is intended to retard or prevent the formation of fuel deterioration products in ground fuels due to auto-oxidation processes and to eliminate the presence of any microbiological growth. It contains a multi functional additive mixture that serves as an antioxidant, metal deactivator, corrosion inhibitor, and detergent/dispersant as well as including a biocide. It is available in either a one-package or two-package system. The two-package system has the fuel biocide as a separate package. The two packages in the two-package system may be used separately, but it is recommended that they be added together.

I.G.1 -- Steps to Follow:

a -- Obtain sufficient Diesel Fuel Stabilizer Additive using the National Stock Numbers (NSNs) as shown in Table 4 (i.e., for the two-package system) and Table 5 (i.e., for the one-package system).

Table 4.

Nomenclature	Container	NSN
Biocide Package (Part of Two-package)	Five gallon can	6840-01-167-6940
	Fifty-five gallon drum	6840-01-041-0098
Stabilizer Package (Part of Two-Package)	Five gallon can	6850-01-167-4789
	Fifty-five gallon drum	6850-01-167-4788

Table 5.

Nomenclature	Container	NSN
Diesel Fuel Stabilizer Additive (One-Package)	Five gallon can	6850-01-246-6544
	Fifty-five gallon drum	6850-01-246-6545

The recommended concentration for the Diesel Fuel Stabilizer Additive packages varies by manufacturer/vendor as shown in QPL-53021.

b -- Prepare the premix by combining fifty percent (50) Diesel Fuel Stabilizer Additive (one-package or two-package systems), as received, with fuel. The two packages in the two-package system may be combined into one premix. Prepare premix in a suitable container such as a Jerry can or one-liter bottle. The premix is now ready for the batch blending process. If the premixing is not possible or practical, the additive may be used directly. The Diesel Fuel Stabilizer Additive package(s), whether in a premix or not, should never be added to a tank that contains no fuel.

I.H -- Blending inside Fuel Tanks.

I.H.1 -- Steps to Follow for Mixing in Tank Vehicles:

a -- Prepare the correctly proportioned premix for the additive or additive combination.

b -- Pour the premix which has been thoroughly agitated into an empty or near empty tank

(NOTE: do not pour the undiluted Diesel Fuel Stabilizer Additive into an empty tank).

c -- Fill the tank with fuel by means of top or bottom loading.

d -- Mix the additive and fuel in the tank. Thorough mixing can be achieved by mixing within the tank using either the on-board fuel transfer pump on an auxiliary pump. If an auxiliary pump is used, it should be grounded to the vehicle chassis. Re-circulation is accomplished by placing the discharge nozzle in the top manhole or access port (See Figure 1.). The nozzle should be secured against slippage and grounded to the vehicle chassis. Filter/separators should be by-passed in order to avoid static electricity build up. All personnel should stay off the top of the tank vehicle during re-circulation. Minimum mixing times should be governed by the formula:

$$Mixing\ \ time = \frac{Total\,Fuel\,Quantity\,(gallons) \times 1/2}{Pump\,Output\,(gallons/\mathrm{min})}$$

e -- If the fuel premix is added to the top of the fuel (i.e., to a tank practically full), mixing times should be doubled. Recommended mixing times for selected tank vehicles are given in Table 6.

f-- If mixing by re-circulation within the tank or tank vehicle is not possible (e.g., no pump or bottom discharge), sufficient agitation may be possible by movement of the tank vehicle such as driving it over a road. The tank must be sufficiently full for the fuel to clear the tank baffles but not so high as to eliminate "sloshing" of the fuel. The fuel vehicle should be driven at a moderate speed over rough terrain for a minimum of fifteen minutes or on a paved roadway for a minimum of one-half hour. If the fuel premix was added on top of the fuel, driving times should be doubled.

I.H.2 --Steps to follow for Mixing in Underground Tanks.

a -- Add the premix to an empty or partially filled tank and load the remaining fuel on top. Adding the premix on to the top of the fuel will require double the mixing time.

b -- With an auxiliary pump, mix the fuel with additive within the fuel tank. A service station type pump cannot effectively circulate the fuel because its flow is too low to be effective (usually no more than 12 gallons/min) and the pump meter is used as a basis of inventory control. An auxiliary pump will require access to two tank access ports (see Figure 2.). The metallic housing of the pump should be grounded to the access port.

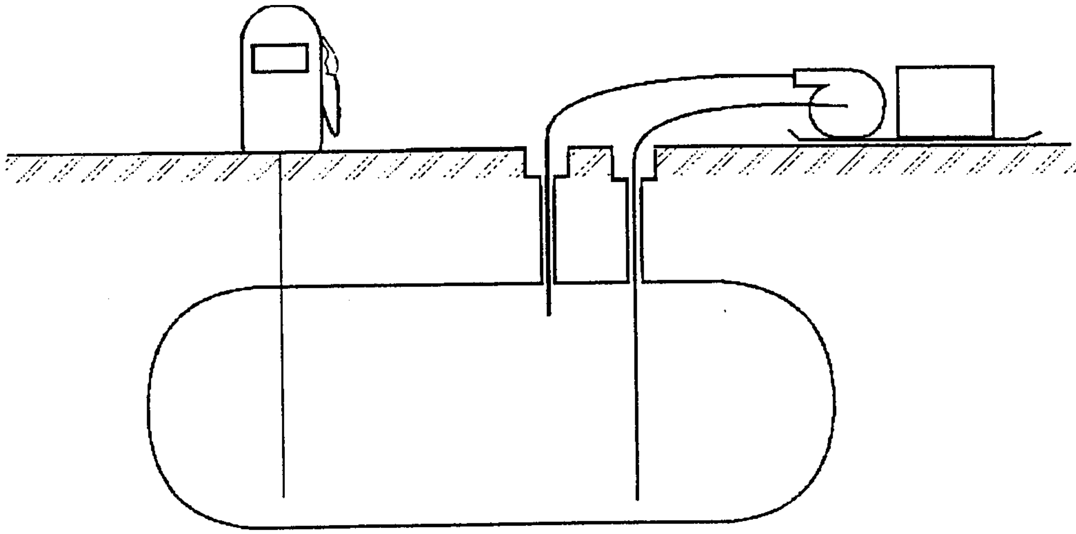

Figure 2.
Mixing in Underground Tank

Table 6.
Mixing Times for Selected Tank Vehicles.

Vehicle	Capacity, gallons	Minimum Pump Rate, gallons/minute	Minimum Mix Time, minutes*
Tank and Pump Unit	1200	50	15
M559 GOER	2500	300	4
M978 HEMTT	2500	300	4
M131 Trailer	5000	225	11
M970 Trailer	5000	60	41

* Assume tank is filled to capacity and pump is running at maximum rate.

II.-- Field Blending of Fuels for Winterization

II.A -- Introduction

Using Blending Fuels such as JP-8 or JP-5 for winterizing diesel or distillate fuels was a long standing practice prior to the Army adopting the Single Fuel On The Battlefield as diesel fuels often created "fuel waxing problems." As diesel fuel continues to be used in some locations, the procedure for field blending of fuels for winterization is being provided. The procedure that follows is the same which is given under NATO Standardization Agreement (STANAG) 2415 entitled "Procedures for Operation of Mechanical Ground Equipment to Minimize Diesel Fuel Problems at Low Ambient Temperatures." The text of this STANAG follows.

Low temperatures can effect fuel properties to the extent that engine driven vehicles and equipment can fail to complete their missions. The principal cause of failure is due to inadequate flow of fuel resulting from either the formation of ice due to water contamination or wax crystals. Ice can clog fuel lines, fuel filters and fuel pumps. Wax crystals build on fuel filter surfaces, fuel pump intake screens or within fuel lines causing fuel starvation.

Ice formation can be prevented by the exclusion of free water from fuel (e.g., use of filter separators), adherence to good housekeeping practices, the application of heat to the fuel system, or by the use of Fuel System Icing Inhibitors (FSII).

Wax crystallization can be prevented by proper fuel selection or by adjustment of the Cloud Point of available fuel for that of the prevailing or anticipated ambient air temperature. Wax crystallization can occur at any temperature below the Cloud Point of the fuel as it generally represents the lower operational limits for equipment utilizing the fuel. Aircraft turbine kerosene base fuels (e.g., JP-8, JP-5, or ASTM JET A-1) have virtually no wax crystallization and will present no problem when used in areas where low ambient temperatures prevail. Military diesel fuel (NATO F-54) has a Cloud Point limit of -13°C maximum which in most instances provides satisfactory low temperature operability. A winterized version of F-54, designated as F-65, has been standardized which consists of a 1:1 mixture of F-54 with JP-8, JP-5, JET A-1 or other kerosenes. Commercial diesel fuels are seasonally adjusted for the winter months, but very often these also require winterization due to unusually low prevailing ambient temperatures or when a summer diesel fuel is inadvertently used during the winter months.

II.B -- General Precautions

Vehicle fuel tanks should be kept full by frequent "topping off" to prevent water condensation within the tank ullage area. Efforts should be made to minimize the possibility of water entry during refueling. Vehicles and equipment should not be refueled from freshly filled refueling vehicles or fuel supply tanks (i.e., sufficient time is needed for the entrained and/or separated water to settle). Fuel supply tanks that have been recently steam cleaned should also be avoided if possible. Fuel inlets and vents should be kept free of accumulated snow and dirt.

Standard filter separators should be used wherever possible during fuel transferring and refueling operations as coalescers and remove much of the free water present in fuel. However, diesel fuels unlike aviation fuels, tend to hold water in suspension due to the presence of naturally-occurring surface active agents (surfactants), making water separation by coalescence less effective. Further, many commercial diesel fuels contain surfactant-type additives such as anti-settling wax agents and dispersants which can cause filter separators to not perform satisfactorily or even become inoperative. In general, effectiveness of filter-separators can be increased by frequent changing of the filter-coalescer elements and by derating the rated capacity (i.e., slowing down the flow rate) by as much as fifty percent.

Fuel storage tanks and filter separators should be drained of bottom water more often during winter operations. Daily draining of bottom sumps is recommended. On board fuel-water separators should be drained daily of accumulated water during winter operations. To prevent ice formation of the separated water, drain water separator sumps immediately after the engine has been shut off. Fuel filters should be changed as directed in the appropriate technical publication.

Procurement procedures for diesel fuels should consider consumption rates (i.e., turnover intervals) as it is essential that the specified Cloud Point values be equal to or lower than the temperature anticipated during the coldest time within that period of use. Every effort should be made to deplete supplies of summer diesel fuel prior to the onset of winter. When the Cloud Point is known to be above the anticipated prevailing low ambient temperatures, provision must be made to "winterize" the fuel.

II.C – Fuel Blending Procedures

Fuel blending to reduce wax content must be performed ***before the onset*** of any anticipated low temperatures. Complete mixing of the two fuels is essential. Appropriate blending fuels are kerosene type fuels such as JP-8, JP-5, JP-7, JET A, JET A-1, and kerosene (ASTM D3699). ***Gasoline or naphtha type fuels should never be used for blending*** as they can substantially reduce the fuel flash point resulting in an increased fire hazard.

II.C.1 – Steps to follow:

a -- The blending ratio can be determined by comparing the Cloud Point values of the base fuel with the blending fuel. The following industry-developed formula is generally applicable for most fuels.

$$K = 100 \times (B-A)/(B-C)$$

(1) Definitions within this formula are as follows:

(a) K = Kerosene blending fuel needed (percent).

(b) B = Cloud Point Index of diesel fuel to be treated.

(c) A = Cloud Point Index of blend (desired value).

(d) C = Cloud Point Index of kerosene blending fuel.

(2) The formula uses a Cloud Point Index value which is based on the Cloud Point of the fuels. Converting Cloud Point values to Cloud Point Index values is accomplished by

use of the chart below which provides tabulation of Cloud Point versus Cloud Point Index.

(3) Although the formula is usable with a wide variety of diesel fuels, there may be some combinations in which this formula does not apply.

b -- Ideally, blending should be performed in either fuel storage tanks, fixed fuel dispensing tanks or refueling vehicles. It is usually not practical to blend in the consuming vehicle's fuel tank. After addition, the mixture should be re-circulated for at least ten minutes. After re-circulation, the mixture should be sampled to ensure a uniform blend. If not uniformly blended, mixture should be re-circulated until a uniform blend is achieved.

c – Those procedures given under **Section I.H** for Blending inside Fuel Tanks (i.e., Tank Vehicles such as the HEMTT, etc.) or for Mixing in Underground Tanks are applicable for blending the kerosene type fuels with diesel fuel.

Table 7.
Cloud Point versus Cloud Point Index

CLOUD POINT, °C	CLOUD POINT INDEX	CLOUD POINT, °C	CLOUD POINT INDEX
+5	268.6	-22	35.1
+4	249.1	-23	32.6
+3	231.0	-24	30.2
+2	214.2	-25	28.0
+1	198.7	-26	26.0
0	184.3	-27	24.1
-1	170.9	-28	22.3
-2	158.5	-29	20.7
-3	147.0	-30	19.2
-4	136.3	-31	17.8
-5	126.4	-32	16.5
-6	117.2	-33	15.3
-7	108.7	-34	14.2
-8	100.8	-35	13.2
-9	93.5	-36	12.2
-10	86.7	-37	11.3
-11	80.4	-38	10.5
-12	74.6	-39	9.7
-13	69.2	-40	9.0
-14	64.1	-41	8.4
-15	59.5	-42	7.8
-16	55.2	-43	7.2
-17	51.2	-44	6.7
-18	47.5	-45	6.2
-19	44.0	-46	5.8
-20	40.8	-47	5.3
-21	37.8	-48	4.9

QPL-25017-19
15 March 2001

QUALIFICATIONS CERTIFIED
OCTOBER 2000

SUPERSEDING
QPL-25017-18
27 February 1998

QUALIFIED PRODUCTS LIST

OF

PRODUCTS QUALIFIED UNDER PERFORMANCE SPECIFICATION

MIL-PRF-25017

INHIBITOR, CORROSION/LUBRICITY IMPROVER, FUEL SOLUBLE

This list has been prepared for use by or for the Government in the acquisition of products covered by the subject specification and such listing of a product is not intended to and does not connote endorsement of the product by the Department of Defense. All products listed herein have been qualified under the requirements for the product as specified in the latest effective issue of the applicable specification. This list is subject to change without notice; revision or amendment of this list will be issued as necessary. The listing of a product does not release or otherwise affect the obligation of the manufacturer to comply with the specification requirements.

THE ACTIVITY RESPONSIBLE FOR THIS QUALIFIED PRODUCTS LIST IS THE AIR FORCE, ASC/ENOI, 2530 LOOP ROAD WEST, WRIGHT-PATTERSON AFB OH 45433-7101. THE QUALIFYING ACTIVITY RESPONSIBLE FOR QUALIFICATION APPROVAL IS AFRL/PRTG, 1790 LOOP ROAD NORTH, WRIGHT-PATTERSON AFB OH 45433-7103.

The products qualified to this QPL are listed in two categories:

a. Category 1 additives are approved for use in fuels which conform to A-A-52557, ASTM D4814, MIL-DTL-5624, MIL-PRF-7024, and MIL-DTL-83133.

b. Category 2 additives are approved for use in fuels which conform to MIL-DTL-5624, MIL-PRF-7024, and MIL-DTL-83133.

The QPL lists the Government designation, which is also the additive identification; the approving office and date of the letter approval, the manufacturer's name and address, and additive specifications.

NOTE: As required by MIL-PRF-25017, the Relative Effective Concentration (REC) was determined by the Rusting Test Method; the Minimum Effective Concentration was determined by either the Ball-On-Cylinder Lubricity Evaluator (BOCLE) or 1.5×REC; and the Maximum Allowable Concentration was determined by the lowest of the following: 54 grams of inhibitor/m^3 of fuel, 4×REC, MicroSeparometer Rating, or the change in electrical conductivity with fuels containing static dissipater additive.

AMSC N/A FSC 6850

DISTRIBUTION STATEMENT A. Approved for public release; distribution is unlimited.

GOVERNMENT/ MANUFACTURER'S DESIGNATION		TEST OR QUALIFICATION REFERENCE	MANUFACTURER'S NAME AND ADDRESS

CATEGORY 1

PRI-19

Relative effective concentration (g/m^3)	6	AFWAL/POSF Ltr, 9 Apr 85	Apollo Technologies International Corp. 5 South Regent Street Suite 526 Livingston NJ 07039-1617
Minimum effective concentration (g/m^3)	18		
Maximum allowable concentration (g/m^3)	22.5		
Density at 15°C (kg/L)	0.89 – 0.91		plant: Apollo Technologies International Corp. c/o Diamond Chemical Company, Inc. Union Ave. & Dubois St. East Rutherford NJ 07073
Viscosity (centistokes at 40°C)	83 – 102		
Flashpoint (°C, minimum)	60		
Neutralization number	100 – 120		
Ash content (%, maximum)	<0.05		
Pour point (°C, maximum)	-18		

DCI-4A

Relative effective concentration (g/m^3)	6	AFWAL/POSF Ltr, 15 Aug 83	Octel Starreon LLC 200 Executive Drive Newark DE 19702-3315
Minimum effective concentration (g/m^3)	9		
Maximum allowable concentration (g/m^3)	22.5		plant: Octel Starreon LLC 7401 Wallisville Road Houston TX 77220
Density at 15°C (kg/L)	0.93 – 0.96		
Viscosity (centistokes at 40°C)	43 – 72		
Flashpoint (°C, minimum)	27		
Neutralization number	100 – 124		
Ash content (%, maximum)	<0.05		
Pour point (°C, maximum)	-18		

DCI-6A

Relative effective concentration (g/m^3)	6	AFWAL/POSF Ltr, 15 Aug 83	Octel Starreon LLC 200 Executive Drive Newark DE 19702-3315
Minimum effective concentration (g/m^3)	9		
Maximum allowable concentration (g/m^3)	9.0		plant: Octel Starreon LLC 7401 Wallisville Road Houston TX 77220
Density at 15°C (kg/L)	0.93 – 0.96		
Viscosity (centistokes at 40°C)	40 – 60		
Flashpoint (°C, minimum)	27		
Neutralization number	120 – 150		
Ash content (%, maximum)	<0.05		
Pour point (°C, maximum)	-18		

GOVERNMENT/ MANUFACTURER'S DESIGNATION		TEST OR QUALIFICATION REFERENCE	MANUFACTURER'S NAME AND ADDRESS

CATEGORY 1

HITEC 580

Relative effective concentration (g/m^3)	6	AFWAL/POSF Ltr, 15 Aug 83	Ethyl Petroleum Additives, Inc. 330 South Fourth Street
Minimum effective concentration (g/m^3)	15		Richmond VA 23219-4304
Maximum allowable concentration (g/m^3)	22.5		plant: Ethyl Petroleum
Density at 15°C (kg/L)	0.91 – 0.925		Additives Division
Viscosity (centistokes at 40°C)	110 – 136		Route 3
Flashpoint (°C, minimum)	66		Sauget IL 62201
Neutralization number	80 – 100		
Ash content (%, maximum)	<0.05		
Pour point (°C, maximum)	-18		

NALCO/EXXON 5403

Relative effective concentration (g/m^3)	6	AFWAL/POSF Ltr, 15 Aug 83	Nalco/Exxon Energy Chemicals, L.P.
Minimum effective concentration (g/m^3)	12	WL/POSF	7705 Highway 90A Sugar Land TX 77478
Maximum allowable concentration (g/m^3)	22.5	Ltr, 15 Mar 93	plants:
Density at 15°C (kg/L)	0.89 – 0.94	WL/POSF	Nalco/Exxon Energy
Viscosity (centistokes at 40°C)	15 – 35	Ltr, 11 May 93	Chemicals, L.P.
Flashpoint (°C, minimum)	60		7701 Highway 90A
Neutralization number	80 – 110		Sugar Land TX 77478
Ash content (%, maximum)	<0.05		
Pour point (°C, maximum)	-18		Anikern(PTY) Ltd. AECI Factory UNBOGINTWINI 4120 South Africa

UNICOR J

Relative effective concentration (g/m^3)	6	AFWAL/POSF Ltr, 15 Aug 83	UOP LLC 25 East Algonquin Road
Minimum effective concentration (g/m^3)	9		P.O. Box 5017 Des Plaines IL 60017-5017
Maximum allowable concentration (g/m^3)	22.5		plant:
Density at 15°C (kg/L)	0.93 – 0.94		UOP McCook
Viscosity (centistokes at 40°C)	55 – 95		8400 Joliet Road
Flashpoint (°C, minimum)	52		P.O.Box 1517
Neutralization number	110 – 126		McCook IL 60525-1517
Ash content (%, maximum)	<0.05		
Pour point (°C, maximum)	-18		

GOVERNMENT/ MANUFACTURER'S DESIGNATION		TEST OR QUALIFICATION REFERENCE	MANUFACTURER'S NAME AND ADDRESS

CATEGORY 1

MOBILAD F800

Relative effective concentration (g/m^3)	6	AFWAL/POSF Ltr, 15 Aug 83	ExxonMobil Chemical Co. P.O. Box 3140
Minimum effective concentration (g/m^3)	12	WL/POSF	Edison NJ 08818-3140
Maximum allowable concentration (g/m^3)	22.5	Ltr, 4 Feb 91	plant: same address
Density at 15°C (kg/L)	0.84 – 0.88		
Viscosity (centistokes at 40°C)	19 – 31		
Flashpoint (°C, minimum)	38		
Neutralization number	80 – 100		
Ash content (%, maximum)	<0.05		
Pour point (°C, maximum)	-43		

NALCO/EXXON 5405

Relative effective concentration (g/m^3)	6	AFWAL/POSF Ltr, 15 Aug 83	Nalco/Exxon Energy Chemicals, L.P.
Minimum effective concentration (g/m^3)	11	WL/POSF	7705 Highway 90A Sugar Land TX 77478
Maximum allowable concentration (g/m^3)	11	Ltr, 15 Mar 93	plant:
Density at 15°C (kg/L)	0.92 – 0.96		Nalco/Exxon Energy
Viscosity (centistokes at 40°C)	40 – 90		Chemicals, L.P.
Flashpoint (°C, minimum)	60		7701 Highway 90A
Neutralization number	130 – 160		Sugar Land TX 77478
Ash content (%, maximum)	<0.05		
Pour point (°C, maximum)	-29		

SPEC-AID 8Q22

Relative effective concentration (g/m^3)	6	AFWAL/POSF Ltr, 2 Mar 89	BetzDearborn 4636 Somerton Road
Minimum effective concentration (g/m^3)	9	WL/POSF	Trevose PA 19053
Maximum allowable concentration (g/m^3)	24	Ltr, 26 May 94	plant: BetzDearborn
Density at 15°C (kg/L)	0.84 – 0.92	WL/POSF	3050 Pegasus Rd.
Viscosity (centistokes at 40°C)	65 – 105	Ltr, 4 Sep 96	Bakersfield CA 93308
Flashpoint (°C, minimum)	50		
Neutralization number	100 – 130	AFRL/PRSF	
Ash content (%, maximum)	<0.05	Ltr, 25 Feb 98	
Pour point (°C, maximum)	-18		
		AFRL/PRSF Ltr, 29 Sep 98	

GOVERNMENT/ MANUFACTURER'S DESIGNATION		TEST OR QUALIFICATION REFERENCE	MANUFACTURER'S NAME AND ADDRESS

CATEGORY 2

TOLAD 4410

Relative effective concentration (g/m^3)	6	AFWAL/POSF Ltr, 15 Aug 83	Baker Petrolite 12645 West Airport Blvd Sugar Land TX 77478
Minimum effective concentration (g/m^3)	9	WL/POSF Ltr, 12 Mar 93	plant: Baker Petrolite 16950 Wallisville Road Houston TX 77049
Maximum allowable concentration (g/m^3)	22.5	AFRL/PRSF Ltr, 12 Oct 00	
Density at 15°C (kg/L)	0.93 – 0.96		
Viscosity (centistokes at 40°C)	120 – 220		
Flashpoint (°C, minimum)	38		
Neutralization number	130 – 155		
Ash content (%, maximum)	<0.05		
Pour point (°C, maximum)	-18		

TOLAD 4445

Relative effective concentration (g/m^3)	6	AFWAL/POSF Ltr, 1 Dec 82	Baker Petrolite 12645 West Airport Blvd Sugar Land TX 77478
Minimum effective concentration (g/m^3)	19	WL/POSF Ltr, 2 Aug 93	plant: Baker Petrolite 16950 Wallisville Road Houston TX 77049
Maximum allowable concentration (g/m^3)	22.5		
Density at 15°C (kg/L)	0.93 – 0.95		
Viscosity (centistokes at 40°C)	10 – 20		
Flashpoint (°C, minimum)	60		
Neutralization number	60 – 80		
Ash content (%, maximum)	<0.05		
Pour point (°C, maximum)	-18		

TOLAD 351

Relative effective concentration (g/m^3)	6	WRDC/POSF Ltr, 18 Apr 90	Baker Petrolite 12645 West Airport Blvd Sugar Land TX 77478
Minimum effective concentration (g/m^3)	9	AFRL/PRSF Ltr, 12 Oct 00	plant: Baker Petrolite 5050 4th Street Southwest Calgary, Alberta T2B 381 Canada
Maximum allowable concentration (g/m^3)	24		
Density at 15°C (kg/L)	0.90 – 0.94		
Viscosity (centistokes at 40°C)	30 – 50		
Flashpoint (°C, minimum)	38		
Neutralization number	95 – 120		
Ash content (%, maximum)	<0.10		
Pour point (°C, maximum)	-18		

GOVERNMENT/ MANUFACTURER'S DESIGNATION		TEST OR QUALIFICATION REFERENCE	MANUFACTURER'S NAME AND ADDRESS

CATEGORY 2

RPS-613

Relative effective concentration (g/m^3)	6	AFRL/PRSF Ltr, 30 Jan 98	Champion Technologies, Inc. P.O. Box 27727 Houston TX 77227-7727
Minimum effective concentration (g/m^3)	9		
Maximum allowable concentration (g/m^3)	22.5		plant: Champion Technologies, Inc. 115 Proctor Odessa TX 79762
Density at 15°C (kg/L)	0.955 – 0.985		
Viscosity (centistokes at 40°C)	80 – 120		
Flashpoint (°C, minimum)	60		
Neutralization number	115 – 160		
Ash content (%, maximum)	<0.05		
Pour point (°C, maximum)	-18		

QPL-53021-9
25 April 2000
SUPERSEDING
QPL-53021-8
03 July 1996

QUALIFICATIONS CERTIFIED
APRIL 2000

QUALIFIED PRODUCTS LIST OF PRODUCTS QUALIFIED UNDER MILITARY SPECIFICATION MIL-S-53021

STABILIZER ADDITIVE, DIESEL FUEL

This list has been prepared for use by or for the Government in the acquisition of products covered by the subject specification and such listing of a product is not intended to and does not connote endorsement of the product by the Department of Defense. All products listed herein have been qualified under the requirements for the product as specified in the latest effective issue of the applicable specification. This list is subject to change without notice, revision or amendment of this list will be issued as necessary. The listing of a product does not release or otherwise affect the obligation of the manufacturer to comply with the specification requirements.

THE ACTIVITY RESPONSIBLE FOR THIS QUALFIED PRODUCTS LIST IS THE U.S. ARMY TANK-AUTOMOTIVE AND ARMAMENTS COMMAND, ATTN: AMSTA-TR-D/210, WARREN MI 48397-5000.

QUAL. NO.	BRAND NAME(S)*/ TREAT RATE(S)**	EXPIRATION DATE	MANUFACTURER'S NAME AND ADDRESS
TWO-PACKAGE ADDITIVES			
SA-12	LTSA-35A (1:5000) and MICROGARD 4000 (1:5000)	02/17/2005	Fuel Quality Services, Inc. Post Office Box 1380 4584 Cantrell Road Flowery Branch, Georgia 30542

* Where two brand names are listed after one qualification number, both products are required.
** Treat Rate is the recommended ratio of additive to fuel; e.g., 1:5000 means 1 gallon of additive to 5000 gallons of fuel.

AMSC N/A FSC 6850