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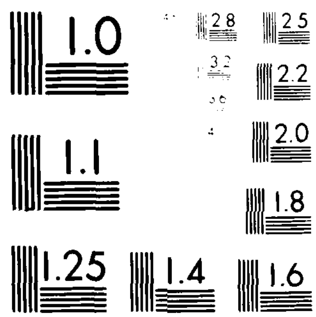

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FINAL REPORT ON FULLY FUELED POMCUS VEHICLE STORAGE TEST PROGRAM

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INTERIM REPORT
AFLRL No. 139

By

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July 1981

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This report discusses the results of a laboratory and field test program conducted to establish the feasibility of storing diesel-fueled vehicles in a fully fueled configuration. In March 1978, approximately twenty vehicles were ~~placed~~ in ~~storage~~ in a POMCUS (Prepositioned Overseas Materiel Configured to Unit Sets) humidity-controlled warehouse in the Federal Republic of Germany. The vehicles were stored fully fueled with NATO F-54 military diesel fuel.

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20. ABSTRACT (cont'd)

Selected vehicles contained additive-treated fuel, while the remaining vehicles contained untreated fuel for comparison purposes. The fuel additives used ~~in this program~~ consisted of a multifunctional additive (corrosion inhibitor, dispersant, metal deactivator, and anti-oxidant) and a biocide. Samples were taken initially and at six-month intervals for analysis during 2½ years of storage. Extensive laboratory evaluations of treated and untreated test fuels under controlled conditions showed a significant improvement in treated test fuel stability. Under field test conditions, differences between treated and untreated fuel were obscured by other variables such as sampling techniques and unknown initial condition of the fuel tanks. Although some of the data were inconclusive, the results indicate that the fuel in the vehicles remained adequately clean and stable throughout the 30-month storage period. No fuel-related vehicle malfunctions occurred during termination of the test in November 1980. Fully fueled vehicle storage for up to 30 months in humidity-controlled warehouses was shown to be feasible when additives are used in the fuel and fuel quality is established.

FOREWORD

The work presented herein was conducted at the U.S. Army Fuels and Lubricants Research Laboratory (USAFLRL), Southwest Research Institute, San Antonio, TX, under Contracts DAAK70-78-C-0001 and DAAK70-80-C-0001. Work was funded by the U.S. Army Mobility Equipment Research and Development Command (USAMERADCOM), Ft. Belvoir, VA, with Mr. F.W. Schaekel (DRDME-GL) serving as contract monitor. Project technical monitor was Mr. M.E. LePera, USAMERADCOM (DRDME-GL).

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I. INTRODUCTION

In 1978 a test program was initiated to evaluate the feasibility of storing European POMCUS (Prepositional Overseas Materiel Configured to Unit Sets) vehicles in a fully fueled configuration. POMCUS vehicles are currently in storage ranging from 1 to 4 years. Storing vehicles in a fully fueled condition can greatly increase the readiness of the vehicles by shortening the time required for post-storage preparation of the vehicles. However, the long-term storage, even under the controlled humidity conditions present in the warehouses, can result in fuel storage-related problems if preventive measures are not taken. Preventive measures include the use of stability additives and regular fuel quality monitoring.

The extent to which a fuel tank is drained, the quality of the residual fuel, the presence of water, the effectiveness of preservative-oil applications, and other factors combine to determine the future residual fuel quality and fuel tank condition. In the case of storing fully fueled equipment, an impending requirement for POMCUS equipment, even more stringent preventive measures were required to avoid fuel and fuel tank deterioration-related problems.

II. DISCUSSION

Under the test program, a given set of vehicles were stored fully fueled for a period of 30 months, some with neat fuel and some with additive-treated fuel. A two-part additive package used to treat the fuel consisted of a biocide, BIOBOR-JF*, at a concentration of 270 ppm, and a fuel stabilizer (dispersant, antioxidant, metal deactivator, and rust inhibitor), FOA-15**, at a concentration of 25 pounds per thousand barrels of fuel. Table 1 lists the vehicles used during the test by vehicle code, vehicle number, vehicle type, and additive treatment. The vehicle codes were assigned to simplify discussions. It is noted that some of the vehicles were dropped from

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**Registered trademark of E. I. DuPont de Nemours, Inc.

TABLE 1. VEHICLES USED IN POMCUS STORAGE PROGRAM

Vehicle Code	Vehicle Number	Vehicle Type Number	Additive Treated
A-1	12AL72	M109	No
A-2	12AL89	M109	Yes
A-3	12AP61	M109	Yes
A-4	9B8772	M109	Yes
A-5	9B8695	M109	Yes
B-1	A9A81671	M578	No
B-2	12FM07	M578	Yes
B-3	12FM75	M578	Yes
B-4	12FM32	M578	No
B-5*	JV005K	M578	No
C-1	12EZ08	M577	No
C-2	12EM03	M577	Yes
C-3	12ET03	M577	Yes
C-4	12EL65	M577	Yes
C-5*	12EY66	M577	No
D-1	04N16269	M35	No
D-2	04K16869	M35	Yes
D-3	04A97570	M35	Yes
D-4	04K9841	M35	Yes
D-5	4N00269	M35	Yes
D-6*	4N30169	M35	No
E-1	4E3765	M49C	Yes
E-2	506059	Pod Truck	No
E-3	593-35	5000-gal.tanker	No
E-4	593-45	5000-gal.tanker	Yes
E-5*	5E0348	Tank & Pump	Yes

* Not Original Fuel Stock; New Fill, New to Program.

the program during the test and were replaced with other vehicles. The vehicles were sampled at 6-month intervals. Fuel samples were shipped to the U.S. Army Fuels and Lubricants Research Laboratory (AFLRL) for analysis, and were also analyzed by the 993rd QM Det in Kaiserslautern, Germany. Table 2 summarizes the sampling of the vehicles.

TABLE 2. SUMMARY OF SAMPLING OF POMCUS VEHICLES

Vehicle Code	0 Month	6 Month	12 Month	18 Month	24 Month	30 Month
A-1	X	X	X	X	X	X
A-2	X	X	X	X	X	X
A-3	X	X	X	X	X	X
A-4	X	X	X	X	X	X
A-5	X	X	X	X	X	X
B-1	X	X	X	X	X	X
B-2	X	X	X	X	X	--
B-3	X	X	X	X	X	--
B-4	X	X	X	X	X	X
B-5	--	X	X	X	X	X
C-1	X	X	X	X	X	X
C-2	X	X	X	X	X	X
C-3	X	X	X	X	X	X
C-4	X	X	X	X	X	X
C-5	--	X	X	X	X	X
D-1	X	X	X	--	X	X
D-2	X	X	X	X	X	X
D-3	X	X	X	X	X	X
D-4	X	X	X	X	X	X
D-5	X	X	X	X	X	X
D-6*	--	--	--	X	X	X
E-1	X	X	--	--	--	--
E-2	X	X	--	--	--	--
E-3	X	--	--	--	--	--
E-4	X	--	--	--	--	--
E-5*	--	--	--	X	X	X

* = Fill Date: April 1979.
x = sampled
-- = not sampled

Before discussing the results of the test, some comments regarding the test vehicles are in order.

There was inconsistency in the method of sampling of the fuel cells in that the samples were not taken from the same part of the fuel cell at each sampling period as indicated below:

Sampling Period	Sampling Level
• 0 month	All level
• 6 months	Bottom
• 12 months	Unknown
• 18 months	Middle
• 24 months	Unknown
• 30 months	Middle

Additionally, it should be noted that all the samples received except for the 30-month samples may not be a true representation of all the fuel in the fuel cell. The fuel samples were taken from vehicles in static storage, and the fuel in the fuel cells was not mixed in any manner before the samples were taken. The products formed by the degradation of fuel can settle to the bottom, giving false test data if the fuel is not mixed in some manner. Prior to taking the 30-month samples, the vehicles were operated for a short period of time in order to mix the fuel. The samples were then taken as soon as the engine had been shut down.

The condition of the fuel cells (i.e., cleanliness and types of materials present) at the time of fueling was not known. Proper cleaning measures were not employed to ensure clean fuel cells before fueling. Also the extended period of time between shipment of samples to receipt at AFLRL could change the results somewhat in that fuel degradation could occur in transit.

Initial untreated fuel (AL-7394-F) and treated fuel (AL-7395-F) were evaluated by four different stability tests, the results of which are found in Tables 3 through 5, and summarized below.

- At 43°C, both fuels are stable in terms of color, gum, and sediment; however, the treated fuel is much more stable.

- At 80°C for 7 days the untreated fuel shows marginal particulate and adherent insoluble values.

- At 100°C (D 873, modified) with 100 psi oxygen for 16 hours, the treated fuel forms less potential residue.

- At 150°C for 90 minutes, the treated fuel is significantly more stable in terms of particulates.

TABLE 3. POMCUS DIESEL (DF-2) FUELS, 43°C STORAGE TEST RESULTS

AFLRL Code No.	7394 (untreated)				7395 (treated)			
	8 wk	12 wk	16 wk	32 wk	8 wk	12 wk	16 wk	32 wk
Particulates, D 2276, 1.2-micrometer, mg/500 ml	0.4	0.8	1.7, 2.4*	1.8, 2.7*	0.2	0.2	0.2, 0.1*	0.1, 0.5*
Steam Jet Gum, D 381, mg/100 ml	11.9	9.6	9.0	11.6	9.8	8.4	8.6	8.2
Color D 1500								
Unfiltered	1.5	2.0	2.0	2.5	1.5	2.0	2.0	2.5
Filtered	1.5	2.0	2.0	2.5	1.5	2.0	2.0	1.5
Total Acid No., D 664 (40-g sample)	0.048	0.031	0.031	0.026	0.048	0.036	0.030	0.021
Light Absorbance,								
Unfiltered Fuel								
650 nm	0.015	0.020	0.025	0.044	0.013	0.013	0.011	0.013
575 nm	0.055	0.066	0.085	0.129	0.051	0.053	0.054	0.062
540 nm	0.105	0.119	0.146	0.204	0.099	0.101	0.106	0.123
500 nm	0.193	0.220	0.265	0.353	0.189	0.193	0.205	0.234
Filtered Fuel								
650 nm	0.013	0.017	0.019	0.030	0.013	0.013	0.014	0.015
575 nm	0.052	0.060	0.076	0.115	0.049	0.057	0.055	0.060
540 nm	0.101	0.110	0.136	0.194	0.098	0.102	0.108	0.120
500 nm	0.190	0.207	0.254	0.336	0.185	0.194	0.207	0.230
Adherent Insolubles, mg/500 ml	3.2	1.4	6.2, 5.2*	4.5, 4.2*	4.4	0.8	0.1, 0.3*	0.1, 0.1*
Visual Inspection,								
Precipitated Sediment	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr
Wall Adherent Gum	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr

*Replicate Test Results

TABLE 4. POMCUS DIESEL (DF-2) FUELS, 80°C STORAGE TEST RESULTS

AFLRL Code No.		7394 (untreated)	7395 (treated)
Particulates, D 2276, 1.2 micrometer, mg/100 ml			
n-heptane	1 Day	0.5	0.3
	3 Days	0.6	0.4
	7 Days	0.9	0.2
Steam Jet Gum, mg/100 ml			
D 381	1 Day	8.0	8.2
	3 Days	9.3	8.3
	7 Days	20.4	13.4
Color Unfiltered/Filtered			
D 1500	1 Day	2.0/2.0	2.0/1.5
	3 Days	2.0/2.0	2.0/1.5
	7 Days	3.0/2.5	2.0/2.0
Light Absorbance, Unfiltered/Filtered Fuel,			
650 nm	1 Day	0.016/0.012	0.015/0.009
	3 Days	0.022/0.013	0.015/0.011
	7 Days	0.102/0.022	0.014/0.010
575 nm	1 Day	0.058/0.052	0.052/0.045
	3 Days	0.072/0.059	0.053/0.046
	7 Days	0.201/0.095	0.055/0.049
540 nm	1 Day	0.110/0.101	0.100/0.091
	3 Days	0.129/0.117	0.103/0.095
	7 Days	0.288/0.172	0.100/0.101
500 nm	1 Day	0.205/0.194	0.193/0.180
	3 Days	0.236/0.223	0.199/0.188
	7 Days	0.445/0.316	0.211/0.203
Adherent Insolubles, mg/100 ml			
	1 Day	5.3	5.0
	3 Days	8.2	10.6
	7 Days	13.9	5.4
Visual Inspection, Precipitated			
Sediment,	1 Day	Tr, Tr	Tr, Tr
Wall Adherent	3 Days	Tr, Tr	Tr, Tr
Gum	7 Days	Small Amt, Tr	Tr, Tr

TABLE 5. POMCUS DIESEL (DF-2) FUELS--RESULTS FROM VARIOUS ACCELERATED STABILITY TESTS

ASTM D 873 (MOD) 16-HR

AFLRL Code No.		7394 (untreated)	7395 (treated)
Odor		Tr Sour	None
Visual Inspection;			
Precipitated Sediment,		Tr	None
Wall Adherent Gum, mg/100 ml		Tr	None
Color (Filtrate) D 1500		3.0	2.5
Precipitate, mg/100 ml		3.7	1.6
Insoluble Gum, mg/100 ml		0.4	0.2
Soluble Gum, mg/100 ml		11.5	8.6

150°C Accelerated Stability Test (90 min)

AFLRL Code No.		7394 (untreated)	7395 (treated)
Particulates, mg/100 ml		6.9	3.5
Steam Jet Gum, D 381, mg/100 ml		19.6	19.8
Color, D 1500 (unfiltered)		3.5	2.5
Color, D 1500 (filtered)		3.0	2.0
Light Absorbance,			
Unfiltered fuel, nm	650	0.145	0.045
	575	0.257	0.118
	540	0.334	0.182
	500	0.494	0.310
Filtered fuel, nm	650	0.075	0.034
	575	0.199	0.101
	540	0.294	0.164
	500	0.491	0.294
Adherent Insolubles, mg/100 ml		7.7	4.1
Visual Inspection			
Precipitated Sediment,		Tr	Tr
Wall Adherent Gum		None	None

The total insolubles values for the ASTM D 2274 accelerated stability test for the untreated base fuel and treated fuel were 1.1 and 0.4 mg/100 ml, respectively. While the additive-treated fuel is significantly more stable, both fuels gave values lower than the 1.5 mg/100 ml limit specified in VV-F-800C.

Table 6 is a summary of the accelerated stability results (from AFLRL) for the 0-, 6-, 12-, 18-, and 30-month samples. The accelerated stability data generally follow a trend of increasing with time. With the exception of samples D-2 and D-4, the only 30-month samples that exceeded specification limits were from vehicles containing neat fuel. Overall, the accelerated stability results tended to be lower for the additive-treated fuel than for the neat fuel.

Anomalies exist in the D 2274 data for the treated versus untreated samples at 12 and 18 months. Vehicle A-5 has high D 2274 values while vehicles A-2 through A-4 remained low, all four of which contained treated fuel. The 6.5 mg/100 ml value at 12 months for vehicle D-2 is anomalous in that at 18 months the value was 0.7 mg/100 ml.

[NOTE: The D 2274 value of 32.5 for vehicle E-1 is anomalous and a one-time sample. It is believed that this unusually high value indicates contamination of the sample source by substances normally not present in diesel fuel. D-6 and E-5 were first time samples and are directionally correct for additive-treated effects; however, the untreated fuel value of 2.0 mg/100 ml is considered high and exceeds specification limit.]

Overall, it is judged that the additive-treated fuel remained more stable as measured by D 2274.

Table 7 is a summary of the AFLRL particulates data for the 0-, 6-, 12-, 18-, 24-, and 30-month samples. Note that in most cases the data follow a general trend of slight increase in particulates from one sampling period to the next. With the exception of samples D-2 and D-4, all of the samples are within specification limits. Generally, there tends to be higher particulates in the additive-treated fuel, possibly due to the dispersant component of the additive acting to keep particulates suspended rather than allowing them to settle out of the fuel.

TABLE 6. SUMMARY OF ASTM METHOD D 2274 ACCELERATED STABILITY VALUES FOR POMCUS FUEL SAMPLES

Vehicle Code	Additive Treated	D 2274, Total Insolubles, mg/100 ml 0 Month	6 Month	12 Month	18 Month	30** Month
A-1	no	1.0	0.3	1.8	1.1	1.2
A-2	yes	0.7	0.3	1.7	0.5	0.4
A-3	yes	1.0	0.4	0.8	0.4	0.3
A-4	yes	--	0.3	0.5	0.7	0.2
A-5	yes	--	0.1	2.5	2.0	2.7
B-1	no	0.9	0.6	0.7	0.7	0.4
B-2	yes	0.3	0.4	0.9	0.5	--
B-3	yes	--	0.6	0.8	1.1	--
B-4	no	0.9	0.4	2.0	1.3	1.3
B-5	no	--	0.3	0.6	0.2	0.2
C-1	no	0.5	1.1	0.9	2.7	2.4
C-2	yes	0.4	0.2	1.3	0.9	0.3
C-3	yes	--	0.2	0.5	0.9	0.3
C-4	yes	0.7	0.3	0.6	0.3	0.3
C-5	no	--	1.2	0.6	1.3	2.7
D-1	no	1.3	0.8	2.6	--	0.3
D-2	yes	2.5	0.3	6.5	0.7	+
D-3	yes	--	0.3	0.2	0.4	0.1
D-4	yes	--	0.3	0.6	0.8	+
D-5	yes	0.6	0.3	1.0	0.8	0.1
D-6*	no	--	--	--	2.0	0.9
E-1	yes	--	32.5	--	--	--
E-2	no	--	1.9	--	--	--
E-3	no	1.1	--	--	--	--
E-4	yes	0.4	--	--	--	--
E-5*	yes	--	--	--	0.3	0.4
Additive Treated						
Average		0.8	2.6¶	1.4@	0.9	0.5
Std.Dev.		±0.7	±8.6	±1.7	±0.4	±0.8
Not Additive Treated						
Average		1.0	0.7	1.3	1.3	1.2
Std.Dev.		±0.3	±0.6	±0.8	±0.8	±0.9

* Fill Date: April 1979.
** 24-month data not available.
\+ Aged sample would not filter due to high particulate level.
-- Not available.
¶ Omitting Vehicle E-1: 0.3 ± 0.1
@ Omitting Vehicle D-2: 1.0 ± 0.6

TABLE 7. SUMMARY OF PARTICULATES FOR POMCUS FUEL SAMPLES

Vehicle Code	Additive Treated	Particulates, D 2276 (mod.) 1.2-micrometer, mg/1000 ml 0 Month	6 Month	12 Month	18 Month	24 Month	30 Month
A-1	no	4.8	0.4	0.4	0.4	0.6	1.6
A-2	yes	5.0	0.4	0.2	0.6	1.1	1.1
A-3	yes	4.2	0.8	0.4	0.6	1.6	2.5
A-4	yes	--	0.2	0.2	0.8	1.1	1.8
A-5	yes	--	0.4	0.2	1.2	0.5	5.0
B-1	no	1.6	0.4	0.2	2.0	0.5	0.3
B-2	yes	7.2	2.6	1.6	0.8	1.1	--
B-3	yes	--	5.8	5.2	1.0	0.6	--
B-4	no	6.8	1.2	1.0	6.4	0.6	4.2
B-5	no	--	0.2	0.4	0.4	0.5	7.1
C-1	no	0.4	0.2	0.2	0.4	0.2	2.1
C-2	yes	2.4	0.4	0.2	1.0	1.4	1.9
C-3	yes	--	0.4	0.2	0.4	0.2	5.0
C-4	yes	2.0	0.4	0.2	0.4	0.5	4.0
C-5	no	--	0.2	0.2	0.4	0.7	5.1
D-1	no	2.0	0.2	0.2	--	1.0	4.4
D-2	yes	6.6	10.2	0.2	7.2	3.3	17.6
D-3	yes	--	1.6	0.8	0.8	0.1	4.5
D-4	yes	--	1.4	0.8	0.8	0.7	19.4
D-5	yes	6.4	0.2	0.2	1.0	3.8	6.6
D-6*	no	--	--	--	1.4	0.5	1.4
E-1	yes	--	1.4	--	--	--	--
E-2	no	--	0.4	--	--	--	--
E-3	no	1.4	--	--	--	--	--
E-4	yes	2.6	--	--	--	--	--
E-5*	yes	--	--	--	0.4	0.5	1.1
Additive Treated							
Mean		4.6	1.9	0.8	1.3	1.2	5.9
Std.Dev.		±2.1	±2.8	±1.4	±1.8	±1.1	±6.2
Not Additive Treated							
Mean		2.8	0.4	0.4	1.6	0.6	3.3
Std.Dev.		±2.4	±0.3	±0.3	±2.2	±0.2	±2.3

*Fill Date: April 1979.

Also, since the dispersant acts to keep some of the particulate matter in suspension, a higher particulate level can be tolerated. With the dispersant, there is less sludge and the majority of the particles are in the size range of 1.2 to 4 micrometers. This size will pass through most fuel filters, but not through a 1.2-micrometer pore size membrane filter.

Table 8 summarizes the AFLRL steam jet gum results for the 0-, 6-, 12-, 18-, 24-, and 30-month samples. Generally, the steam jet gum results do not show

TABLE 8. SUMMARY OF STEAM JET GUM DATA FOR POMCUS FUEL SAMPLES

Vehicle Code	Additive Treated	ASTM Method D 381, Steam Jet Gum, mg/100 ml 0 Month	6 Month	12 Month	18 Month	24 Month	30 Month
A-1	no	57.0(1)	8.0	6.7	7.6	6.5	22.8(3)
A-2	yes	33.0(1)	5.1	10.0	9.8	12.9	26.6(3)
A-3	yes	29.1(1)	8.0	9.0	10.3	9.5	13.3
A-4	yes	(2)	11.3	23.9	23.7	13.3	14.1
A-5	yes	(2)	22.7	51.2	2.3	27.0	35.3(3)
B-1	no	160.0(1)	13.8	63.7	50.4	7.5	11.4
B-2	yes	122.0(1)	6.9	9.0	8.3	7.3	(2)
B-3	yes		7.3	7.6	10.1	6.5	(2)
B-4	no	51.2(1)	6.9	7.8	9.0	7.5	11.9
B-5	no	(2)	8.8	14.2	8.5	8.4	14.4
C-1	no	6.3	10.7	7.0	6.6	7.4	21.7(3)
C-2	yes	7.3	7.7	4.5	13.1	10.4	108.8(3)
C-3	yes	(2)	25.1	36.4	50.2	(3)	85.9(3)
C-4	yes	7.2	8.4	12.8	20.0	8.3	16.7
C-5	no	(2)	5.3	10.5	10.1	5.0	11.0
D-1	no	83.2(1)	11.6	9.9	69.0	12.3	15.5
D-2	yes	102.1(1)	7.2	32.9	91.1	(3)	124.7(3)
D-3	yes	(2)	108.3	11.8	37.8	(3)	147.0(3)
D-4	yes	(2)	64.6	5.7	20.8	45.8	98.9(3)
D-5	yes	12.9	19.2	24.7	(2)	(4)	48.1(3)
D-6	no	(2)	(2)	(2)	(2)	4.0	7.2
E-5	yes	(2)	(2)	(2)	3.9	3.2	5.9

(1) Analyses performed using air jet rather than steam jet method.
(2) No data available.
(3) Sample was still wet after 1 hour in heating block.
(4) Sample contaminated by water.

as much of a trend of increasing with time as do the particulates and accelerated stability results. Overall, the 30-month results tend to be higher than the previous samples. This is to be expected due to the increase in storage time; however, the high values in some of the early samples could indicate the presence of higher boiling materials such as preservative oils. It is also expected that the additive-treated samples could have a slightly higher steam jet gum result than the neat samples due to the polymer present in the additives.

During termination of the test, the fuel filler pipes were inspected, and the results are summarized in Table 9. The vehicle engines were then started (some of which required ether) and run for approximately 1 hour each. Due to the restricted maneuvering area in the warehouse vicinity, approximately 1.5 and 10 miles were put on the tracked and wheeled vehicles, respectively. Two fuel samples (each 1 gallon) were then obtained in addition to removing the primary fuel filters for visual inspection. Of the eighteen vehicles involved, two were not fully operational. Vehicle No. 9B8695 (M109) could not be started due to starter problems, and Vehicle No. 12FM32 (M578) was run only long enough to get it out of the warehouse, because the secondary fuel filter housing gasket was missing and leaking fuel profusely. Figure 1 contains photographs showing standard POMCUS warehouse vehicle storage and vehicles being towed out of the warehouse and fueled before driving away. The last photograph in Figure 1 shows a fully fueled vehicle in the current program being started in the warehouse and driven out.

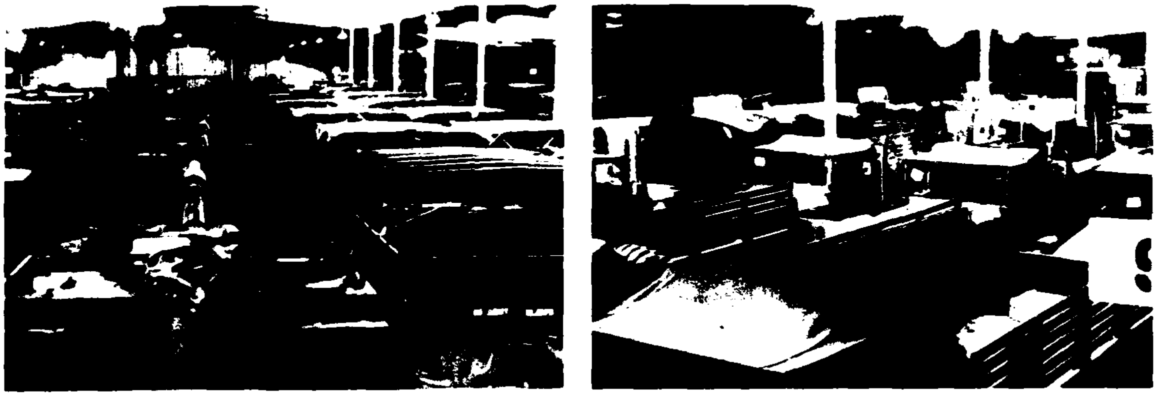
Throughout the course of the test, two sets of samples were taken from each vehicle at each sampling period. One set of samples was shipped to AFLRL for analysis. The results of these analyses are reported herein and in References 1 and 2. The other set of samples was submitted for analysis to the 993rd QM Det (PPL, B) laboratory located in Kaiserslautern, Germany.

The 993rd laboratory is equipped to perform most of the usual specification tests on fuel samples. Table 10 is a compilation of the accelerated stability, carbon residue, total acid number, and particulates data for the 30-month

TABLE 9. POMCUS VEHICLE FUEL FILLER PIPE INSPECTION RESULTS

Vehicle Number	Vehicle Type	Additive Treated	Filler Pipe Inspection
12AL72	M109	no	Good condition, no grease
12AL89	M109	yes	Good condition, no grease, torn screen
12AP61	M109	yes	Good condition, no grease
9B8772	M109	yes	Good condition, no grease
9B8695	M109	yes	Good condition, no grease
A9A01671	M578	no	Fuel cell bladders installed TM-9-237 (Good condition)
12FM07+	M578	yes	---
12FM75+	M578	yes	---
12FM32	M578	no	Probably not bladder; fuel: dark, dirty, appears to be just oil, no cover
JV005K*	M578	no	Fuel cell bladder installed, good condition
12EZ08	M577	no	6 ft pipe good condition
12EM03	M577	yes	6 ft pipe good condition
12ET03	M577	yes	6 ft pipe good condition
12EL65	M577	yes	6 ft pipe good condition
12EY66*	M577	no	6 ft pipe good condition
04N16269	M35	no	Very, very slight white corrosion, copper scratched
04K16869	M35	yes	"Stinks"-old filler pipe, copper showing; preservative grease turned milky white, extensive corrosion
04A97570	M35	yes	Preservative grease on cap, slight corrosion (1 in^2) two inches above fuel line
04K9841	M35	yes	Scratched to copper in some places, old? Slight corrosion over whole surface above fuel line
4N00269	M35	yes	Some scraped copper showing; very slight corrosion
4N30169*	M35	no	---
4E3765	M49C	yes	---
506059	Pod truck	no	---
593-35	5000-gal. tanker	no	---
593-45	5000-gal. tanker	yes	---
5E0348*	Tank & Pump	yes	---

* Not original fuel stock; new fill, new to program.
\+ Vehicle dropped from program.



a. POMCUS Warehouse Vehicle Storage

b. Vehicle Being Towed Out of Warehouse

c. Vehicle Being Fueled Before Drive Away

d. Fully Fueled Vehicle Being Started in POMCUS Warehouse and Driven Out

FIGURE 1. POMCUS WAREHOUSE VEHICLE STORAGE PROCEDURES FOR DRIVE AWAY AND FULLY FUELED STORAGE

fuel samples, as determined by the 993rd laboratory. Table 11 is a listing of the particulates data, from the 993rd laboratory, for 18-, 24-, and 30-month samples and also accelerated stability data for the 24- and 30-month samples. The 993rd lab was not equipped to run these tests prior to these periods.

TABLE 10. LABORATORY RESULTS OF POMCUS 30-MONTH FUEL SAMPLE

Analyses performed by 993rd QM Det.

Vehicle Code	Additive Treated	Accelerated Stability, D 2274 Total Insolubles, mg/100 ml	Carbon Residue 10% Bottoms, wt%	Total Acid Number D 664 mg KOH/g Sample	Particulates, D 2276 1.2 μm, mg/1000 ml
A-1	no	0.62	0.19	0.07	8.5
A-2	yes	0.51	0.16	0.06	11.6
A-3	yes	0.68	0.17	0.07	18.6
A-4	yes	1.25	0.11	0.07	38.8
A-5	yes	0.77	0.20	0.06	5.7
B-1	no	1.45	0.13	0.07	21.8
B-4	no	0.82	0.16	0.06	0.7
B-5	no	0.20	0.09	0.09	2.9
C-1	no	1.31	0.18	0.06	4.6
C-2	yes	0.65	0.19	0.06	16.8
C-3	yes	0.51	0.20	0.07	1.5
C-4	yes	0.28	0.11	0.07	2.6
C-5	no	0.88	0.14	0.07	2.1
D-1	no	0.68	0.32	0.09	10.5
D-2	yes	0.68	0.70	0.38	14.6
D-3	yes	0.65	0.19	0.06	0.1
D-4	yes	1.62	0.20	0.07	0.1
D-5	yes	0.42	0.15	0.07	0.1
D-6	no	0.28	0.11	0.09	5.4
E-5	yes	0.60	0.13	0.06	0.2

TABLE 11. LABORATORY RESULTS OF POMCUS FUEL SAMPLE

Analyses performed by 993rd QM Det (PPL, B).

Vehicle Code	Additive Treated	Particulates, ASTM D 2276, 1.2 μm, mg/1000 ml			Accelerated Stability, ASTM D 2274, Total Insolubles, mg/100 ml	
		18 Month	24 Month	30 Month	24 Month	30 Month
A-1	no	1.00	0.53	8.52	1.2	0.6
A-2	yes	4.47	1.14	11.60	1.7	0.5
A-3	yes	6.26	1.30	18.60	0.5	0.7
A-4	yes	2.46	0.71	38.80	0.4	1.3
A-5	yes	4.03	0.71	5.66	0.8	0.8
B-1	no	1.31	0.40	21.79	0.6	1.5
B-2	yes	3.82	3.03	+	2.6	+
B-3	yes	6.70	8.96	+	2.4	+
B-4	no	1.70	1.11	0.70	0.9	0.8
B-5	no	1.88	0.70	2.87	1.6	0.2
C-1	no	0.20	1.15	4.55	1.5	1.3
C-2	yes	0.90	1.70	16.76	1.0	0.7
C-3	yes	0.21	4.42	1.50	1.0	0.5
C-4	yes	0.10	4.50	2.62	0.6	0.3
C-5	no	0.24	4.44	2.05	2.8	0.9
D-1	no	3.20	2.36	10.52	0.6	0.7
D-2	yes	1.10	44.18	14.55	2.1	0.7
D-3	yes	1.72	1.42	0.03	0.8	0.7
D-4	yes	2.07	1.87	0.03	1.1	1.6
D-5	yes	0.63	0.39	0.10	0.6	0.4
D-6	no	3.07	1.33	5.41	2.7	0.3
E-5	yes	6.70	2.19	0.21	0.3	0.6

+ Samples dropped from program.

It is noted that many anomalies exist throughout the data from the 993rd laboratory, especially in the particulates data. In many instances, the particulates data do now show a trend of steady increase in test results; and although some increase in the amount of particulates was expected, the magnitude of increase as indicated by the 993rd data can not be readily explained or confirmed. Also, in a 2-year test at Aberdeen Proving Ground, the particulates data varied in a cyclic pattern (3).*

Table 12 contains the laboratory data for the 30-month samples as determined at AFLRL. Examination of the data indicates that the fuel in most of the vehicles remained relatively clean and stable throughout the 30-month storage period. Generally, the additive-treated fuel samples exhibited more desirable stability characteristics than did the neat fuel samples. Some anomalies do exist, however, such as vehicle E-5 which gave a low D 2274 value (0.4 mg/100 ml) but a relatively high 150°C 3-hour result (11.0 mg/ml).

The fuel samples from vehicles D-2 and D-4 exhibited poor results for most of the tests performed. It should be noted that these vehicles also had much visible corrosion in the fuel tank area (see Table 9) which could account for some of the decrease in the quality of the fuel. Although these two vehicles contained additive-treated fuel, the majority of the corrosion occurred above the fuel line. Since the additive package does not contain a volatile corrosion inhibitor, the nonfuel-wetted surfaces are afforded no corrosion protection. Figure 2 is a photograph of the fuel filler pipe from vehicle no. 04K16869 (D-2). Note that the most extensive corrosion (the cause of which has not been determined) is in the upper two-thirds of the filler pipe where fuel was not in constant contact with the metal. Corrosion debris could also have further catalyzed degradation of the fuel.

In addition to visual inspections of the fuel filler pipe area of each vehicle, the primary fuel filters were removed and inspected. Based on the results of this preliminary inspection, the filters were either discarded or returned to AFLRL for further analysis. Four filters, from Vehicle Nos. 12EZ08, 12EY66, 12FM32, and 04K16869, were returned for analysis. Figure 3 is a photograph of the filter from Vehicle No. 12EY66. Each filter underwent a

*Underscored numbers in parentheses refer to list of references at the end of this report.

TABLE 12. LABORATORY DATA FOR POMCUS 30-MONTH FUEL SAMPLES

Vehicle Code	A-1	A-2	A-3	A-4	A-5	B-1	B-2**	B-3**	B-4	B-5
Additive Treated	no	yes	yes	yes	yes	no	x	x	no	no
Accelerated Stability, D 2274, Total Insolubles, mg/100 ml	1.2	0.4	0.3	0.2	2.7	0.4	--	--	1.3	0.2
Particulates, D 2276, 1.2 micrometer, mg/1000 ml	1.6	1.1	2.5	1.8	5.0	0.3	--	--	4.2	7.1
150°C Accelerated Stability, Total Insolubles, mg/100 ml										
1.5 hr	1.5	0.1	0.7	0.3	0.7	0.1	--	--	1.5	2.2
3.0 hr	5.9	0.1	0.7	0.8	1.4	1.4	--	--	5.9	3.1
Steam Jet Gum, D 381, mg/100 ml	22.8+	26.6+	13.3	14.1	*35.3	11.4	--	--	11.9	14.4
Total Acid Number, D 664, mg KOH/g sample	0.05	0.05	0.05	0.04	0.05	0.04	--	--	0.04	0.05
Visual Inspection	C+B	C+B	C+B	C+B	C+B	C+B	--	--	C+B	C+B
Color, D 1500	2.5	2.5	2.5	2.0	2.5	2.0	--	--	2.5	1.5
Light Absorbance at										
650 nm	0.019	0.020	0.027	0.018	0.020	0.012	--	--	0.015	0.007
575 nm	0.073	0.073	0.080	0.055	0.064	0.041	--	--	0.057	0.028
540 nm	0.141	0.140	0.147	0.101	0.116	0.079	--	--	0.110	0.056
500 nm	0.253	0.251	0.260	0.184	0.212	0.140	--	--	0.194	0.100

* Samples did not dry after 1 hour in steam block.
\+ Sample was still wet after 1 hour in steam block.
Filters remained plugged after 2 hours of filtration.
** Dropped from program.

Vehicle Code	C-1	C-2	C-3	C-4	C-5	D-1	D-2	D-3	D-4	D-5	D-6	E-5
Additive Treated	no	yes	yes	yes	no	no	yes	yes	yes	yes	no	yes
Accelerated Stability, D 2274, Total Insolubles, mg/100 ml	2.4	0.3	0.3	0.3	2.7	0.3	@	0.1		0.1	0.9	0.4
Particulates, D 2276, 1.2 micrometer, mg/1000 ml	2.1	1.9	5.0	4.0	5.1	4.4	17.6	4.5	19.4	6.6	1.4	1.1
150°C Accelerated Stability, Total Insolubles, mg/100 ml												
1.5 hr	2.5	0.3	0.5	0.6	4.8	0.3	5.3	0.6	1.0	0.3	2.3	3.4
3.0 hr	8.3	0.1	2.6	2.9	8.7	0.7	6.9	0.9	1.5	0.1	3.2	11.0
Steam Jet Gum, D 381, mg/100 ml	21.7+	*108.8	*85.9	16.7	11.0	15.5	*124.7	*147.0	*98.9	*48.1	7.2	5.9
Total Acid Number, D 664, mg KOH/g sample	0.04	0.05	0.07	0.04	0.06	0.05	0.03	0.06	0.05	0.07	0.05	0.05
Visual Inspection	C+B	C+B	C+B	C+B	C+B	C+B	Cloudy	C+B	C+B	C+B	C+B	C+B
Color, D 1500	2.0	2.5	2.5	2.0	1.5	2.5	3.0	2.5	2.5	2.5	1.0	1.0
Light Absorbance at												
650 nm	0.013	0.019	0.013	0.017	0.011	0.023	0.256	0.017	0.023	0.023	0.007	0.001
575 nm	0.052	0.066	0.055	0.056	0.041	0.065	0.375	0.058	0.063	0.065	0.024	0.014
540 nm	0.103	0.122	0.106	0.105	0.072	0.116	0.493	0.112	0.113	0.119	0.040	0.031
500 nm	0.182	0.220	0.196	0.188	0.121	0.211	0.700	0.216	0.207	0.220	0.064	0.055

* Samples did not dry after 1 hour in steam block.
\+ Sample was still wet after 1 hour in steam block.
@ Filters remained plugged after 2 hours of filtration.

heptane and sonic cleaner rinse. The residue from this rinse was collected, oven dried, and analyzed by various methods. Table 13 lists the results of analysis of the residues by quantitative X-ray fluorescence. Note that all samples show relatively high levels of iron in the residue. This could be a sign of corrosion in the fuel system or possibly contaminaton from an external source. There also exists high amounts of zinc and lead in some of the samples. The presence of these two elements is probably the result of surface corrosion of the fuel tank/filler pipe. Infrared (IR) analysis was also performed on each of the heptane insoluble residue samples. Figures 4 through 7

FIGURE 2. FUEL FILLER PIPE FROM POMCUS VEHICLE NO. 04K16869

FIGURE 3. FUEL FILTER FROM POMCUS VEHICLE NO. 12EY66

TABLE 13. ELEMENTAL ANALYSIS OF POMCUS FUEL FILTER RESIDUES (Wt% of Element Detected)				
Element	12EZ08	12EY66	04K16869	12FM32
Mg	0.17	0.72	0.17	0.12
Al	0.62	1.03	0.28	0.15
Si	1.85	1.74	1.21	0.44
P	*	0.11	*	0.09
S	1.46	3.18	4.01	0.58
Cl	*	0.46	*	0.23
Ca	1.78	3.25	0.39	4.22
Ti	0.15	0.31	0.09	0.04
Ba	0.51	1.25	0.33	0.07
V	0.02	0.08	*	*
Cr	0.09	0.39	0.08	*
Mn	*	0.12	*	*
Fe	11.80	5.46	1.09	25.58
Cu	0.21	0.60	0.13	0.13
Zn	2.42	0.81	0.48	1.11
Pb	3.75	0.77	39.84	0.16
Br	0.04	0.06	*	*

*None detected.

are the IR spectra for each of the samples. Microbiological debris usually has absorption bands in the 5.9- to 6.1-micrometer range as well as at 3 and 6.54 micrometers. Fuel degradation products have absorption bands at 3, 5.8, and 6.25 micrometers. Examination of the IR spectra (Figures 4 through 7) shows that each sample potentially contains some microbiological debris but mainly fuel degradation products. Microscopic examination of the residues shows some microbiological debris, rust, and dirt, and a large amount of particles less than 2 micrometers in size. Figure 8 is a photograph of a representative microscopic field taken during the examination of the filter residue from Vehicle No. 12FM32.

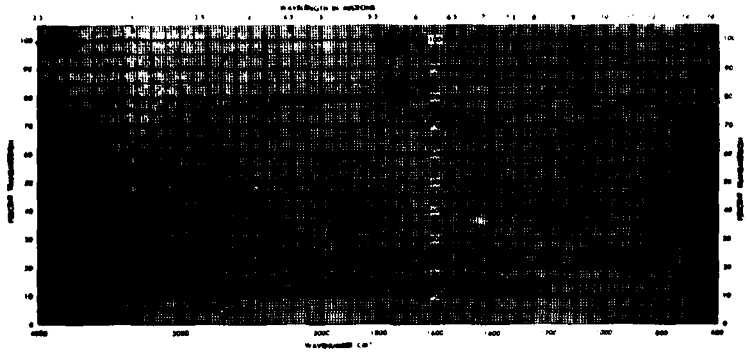


FIGURE 4. INFRARED SPECTRUM OF HEPTANE INSOLUBLE RESIDUE FROM POMCUS VEHICLE FUEL FILTER--VEHICLE NO. 12EZ08

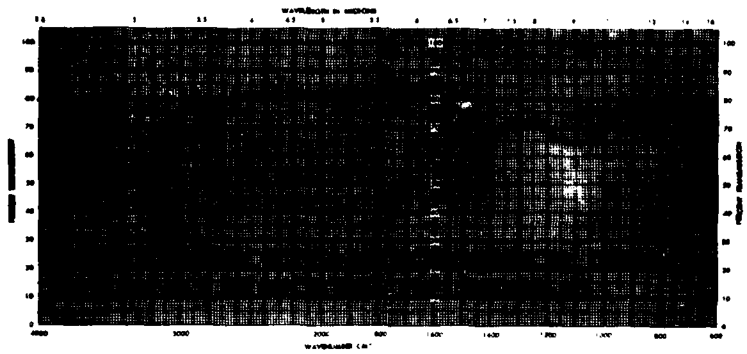


FIGURE 5. INFRARED SPECTRUM OF HEPTANE INSOLUBLE RESIDUE FROM POMCUS VEHICLE FUEL FILTER--VEHICLE NO. 12EY66

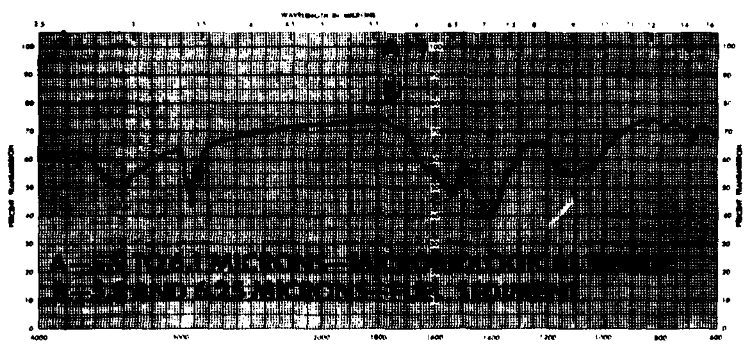


FIGURE 6. INFRARED SPECTRUM OF HEPTANE INSOLUBLE RESIDUE FROM POMCUS VEHICLE FUEL FILTER--VEHICLE NO. 04K16869

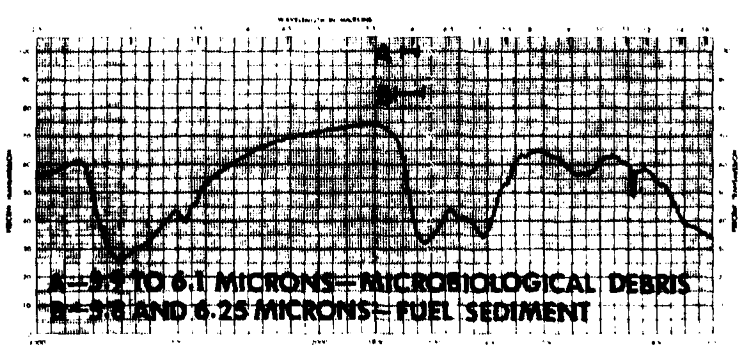


FIGURE 7. INFRARED SPECTRUM OF HEPTANE INSOLUBLE RESIDUE FROM POMCUS VEHICLE FUEL FILTER--VEHICLE NO. 12FM32

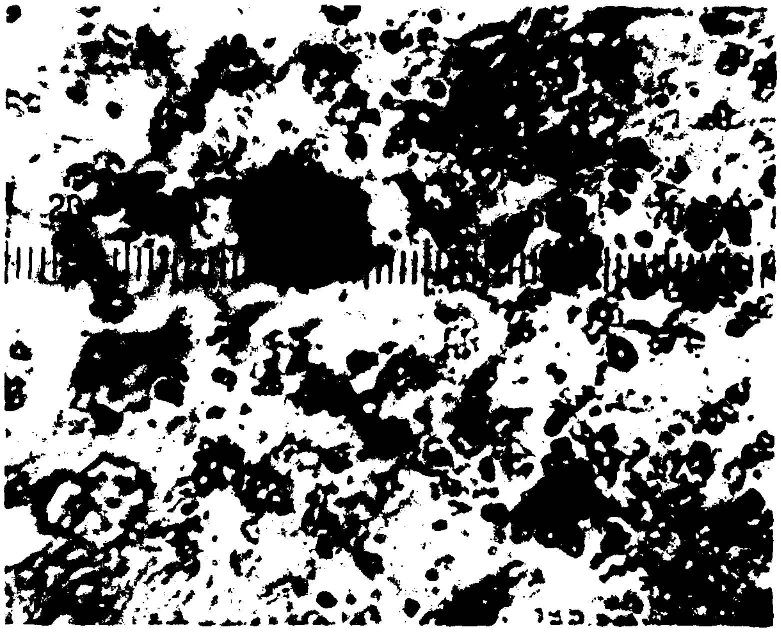


FIGURE 8. PHOTOGRAPH OF HEPTANE INSOLUBLE RESIDUE FROM POMCUS VEHICLE FUEL FILTER--VEHICLE NO. 12FM32
(Note: Oil wetted lens--1.0μm/scale division)

During the termination, a prototype Field Fuel Tester was used on site to estimate the cleanliness of several of the fuel samples. Table 14 is a comparison of the field results with those obtained by laboratory analysis.

TABLE 14. COMPARISON OF PARTICULATES DATA OBTAINED BY LABORATORY ANALYSIS AND USING THE AFLRL PROTOTYPE FIELD FUEL QUALITY MONITOR

Vehicle Code	Laboratory[a] Data	Field[b] Data
B-1	0.3	2.3
A-2	1.1	4.3
A-1	1.6	6.8
A-3	2.5	3.9
D-1	4.4	7.3
D-3	4.5	3.3
D-5	6.6	2.8
D-2	17.6	9.9
D-4	19.4	3.3

(a) Particulates, D 2276, (mod.) 1.2 micrometer, mg/1000 ml.
(b) Particulates, Glass Fiber Filter, mg/1000 ml.

Although there is some difference between results for the same sample, the field results do tend to be close and generally trend in like manner to the laboratory data. However, it should be noted that the laboratory test and the field test operate on different principles; the laboratory test being gravimetric, while the field test relies on light absorption by the contaminants, making the field test susceptible to particulate color.

With respect to current status, all testing is complete. Approval for and authority to initiate fueling of POMCUS diesel powered vehicles from the Department of the Army is being pursued by the Office of the Deputy Chief of Staff of Logistics (See Reference 4).

III. CONCLUSIONS AND RECOMMENDATIONS

- Under controlled laboratory conditions, the treated test fuel was significantly more stable than the untreated test fuel, as measured by a variety of fuel stability test techniques.

- Under the conditions of the POMCUS storage tests, fully fueled vehicles were successfully stored for 30 months. These conditions included a stable base fuel, use of the stabilizer additive package, and warehouse storage under controlled humidity. Some corrosion of metal surfaces did occur but this was primarily on nonfuel-wetted surfaces (fuel filler pipe and cap) where corrosion protection from the additive-treated fuel was not available. No fuel-related malfunctions occurred during the termination procedure, which included starting and operating the vehicles.

- Under field test conditions, there are many additional uncontrolled factors which tend to obscure the differences between treated and untreated fuel. These include sampling techniques, shipping time, and unknown initial condition of fuel tanks.

- Phased implementation of fully fueled diesel vehicle storage is completely feasible, provided proper use of additives and fuel quality is initially established, and subsequent "spot" sampling of stored vehicles for fuel quality monitoring is conducted.

IV. REFERENCES

1. Letter from AFLRL to MERADCOM (DRDME-GL), dated 11 July 1980, with the subject "Summary of POMCUS Fully Fueled Vehicle Storage Program Data After Eighteen Months of Storage."

2. Letter from AFLRL to MERADCOM (DRDME-GL), dated 10 September 1980, with the subject "Analytical Data for Two-Year Fuel Samples From POMCUS Vehicles Fully Fueled Test."

3. "How Stable is Diesel in Storage?" LePera, M.E. and Sonnenburg, J.G., Hydrocarbon Processing, pp 111-115, September 1973.

4. Memorandum from Deputy Chief of Staff for Logistics, DALO-TSE (LTC Bila) to Chief of Staff, Army; no date; subject "Fueling of POMCUS Equipment in Storage"--Decision Memorandum. The purpose of the memorandum is "To obtain approval for and authority to initiate fueling of POMCUS diesel consuming vehicles." The memorandum has concurrence from ODCSPER, ODCSOPS, USAREUR, and DARCOM.

V. BIBLIOGRAPHY

1. Letter from MERADCOM (DRDME-GL) dated 26 July 1977 with the subject "Proposed Test Plan for POMCUS Field Test."

2. Letter from AFLRL to MERADCOM (DRDME-GL) dated 29 September 1977, with subject "POMCUS Fuel Samples and Additives for POMCUS Fully Fueled Vehicles Test Program."

3. Letter from AFLRL to MERADCOM (DRDME-GL) dated 20 July 1978 with the subject "Technical Liaison Visit to USAEMMC in Zweibrucken and POMCUS Storage Warehouse in Miseau, FRG, Regarding Cooperative Program for Storage of Fully Fueled Vehicles."

4. Letter from AFLRL to MERADCOM (DRDME-GL) dated 23 February 1979, with the subject "Analytical Data for Fuel Samples from POMCUS Vehicles Fully Fueled Test."

5. Letter from MERADCOM (DRDME-GL) dated 30 May 1979 with the subject "Analytical Data on POMCUS Fuel Samples."

6. Letter from AFLRL to MERADCOM (DRDME-GL) dated 26 September 1978, with the subject "Analytical Data for Fuel Samples from POMCUS Vehicles Fully Fueled Test."

7. Letter from AFLRL to MERADCOM (DRDME-GL) dated 18 April 1980 with the subject "Analytical Data for (18 months) Fuel Samples from POMCUS Vehicles Fully Fueled Test."

8. Trip report for Messrs. L.L. Stavinoha and S.R. Westbrook for the period 17-21 November 1980.

9. Letter from AFLRL to MERADCOM (DRDME-GL), dated 21 May 1981 with the subject "Laboratory Data for Fuel Samples Taken During Termination of POMCUS Fully Fueled Vehicle Test."

10. Trip report for DRDME-GL (J.V. Mengenhauser) for the period 2-9 September 1980.

11. TWX Communication from Commander, 21st Support Command dated 7 December 1980 with the subject "POMCUS Fully Fueled Test Program."

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