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FUEL-ELASTOMER COMPATIBILITY STUDIES

Results of 80°C/14-Day Exposure Experiments

INTERIM REPORT
BFLRF No. 231

By

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<p>Five collapsible, elastomer-coated fabric products were exposed to four middle distillate fuels and to a middle distillate fuel simulant. The coated fabrics were represented by a drum material, a pillow tank fabric and its seam section, and a berm liner with its seam section. Each of these samples was treated as individual materials.</p> <p>Compatibility of these products was studied under accelerated conditions, during which each elastomer was submerged in each fuel for 14 days at 80°C.</p> <p>The effects of the fuels on the elastomers and the effects of the elastomers on the fuels were evaluated using visual observations, photomicrographs, infrared spectroscopy, and measurement of hardness, color, gum, and water contents. <i>Keywords: Accelerated Testing, Fuel Tank, K-2,</i></p>			
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EXECUTIVE SUMMARY

Problems and Objectives: The U.S. military experienced catastrophic degradation of collapsible fuel tanks in the field. These tanks were used to store middle distillate fuels under tropical environments. The objective of this effort was to evaluate, under accelerated test conditions, the mutual effects of existing middle distillate fuels and a model compound based middle distillate fuel simulant, and those fielded elastomer-coated fabric materials that are used for fuel containment.

Importance of Project: Through such studies, the degradation processes of elastomeric fuel tanks are better understood. Such knowledge should lead to improvements in the fuel tank materials and their selection, thus increasing the service life of collapsible fuel tanks and alleviating contamination of fuels and the environment.

Technical Approach: In an accelerated compatibility study, selected elastomers were exposed to various middle distillate fuels and to a fuel simulant at 80°C for 14 days. The effects of exposure were evaluated by chemical and physical measurements.

Accomplishments: Several aspects of fuel-elastomer incompatibility were noted, and recommendations were made to alleviate these problems. The following problem areas were observed:

- Some fuel tanks are designed to provide fuel resistance internally and to resist the elements at their outer surfaces. In such cases, tank degradation may result when fuel is spilled on the outer surfaces. Such tank construction may lead not only to physical loss of fuel to the environment, but also lead to fuel contamination.
- Some elastomers gave indications that they contained unreacted isocyanates, which continued to react under the exposure conditions of these experiments.
- The fuels and the fuel simulant extracted a plasticizer from some elastomers that are intended to be used as berm liners. Such action may adversely affect the long-term integrity and usefulness of these elastomers.
- The presence of talc, used to prevent unwanted adherence of layers of elastomers, was detected. The possible effects of this talc is unknown at this time.
- The tentative middle distillate fuel simulant gave reproducible results that were similar, but marginally more severe than those obtained through the use of JP-8.

Military Impact: This study should lead to improvements in the fuel tank materials and their selection, thus increasing the service life of collapsible fuel tanks and alleviating contamination of fuels and the environment.

FOREWORD

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I. INTRODUCTION

The objective of this effort was to evaluate, under accelerated test conditions, the mutual effects of existing middle distillate fuels and a middle distillate fuel simulant, and those fielded elastomer-coated fabric materials that are used for fuel containment.

It was anticipated that, through such studies, the degradation processes of elastomeric fuel tanks will be better understood. Such knowledge should lead to improvements in the fuel tank material selection, thus increasing the service life of collapsible fuel tanks.

According to project plans, selected elastomers were exposed to various fuels and to a fuel simulant at 80°C for 14 days. The effects of the exposure were evaluated by chemical and physical measurements.

II. EXPERIMENTAL APPROACH

A. Selection of Materials

The selected elastomeric materials included a sample of the following materials:

- Towable fuel drum material: Elastomer A;
- Collapsible fuel tank material and associated seam section: Elastomers B and C, respectively;
- Berm liner and its seam section: Elastomers D and E, respectively.

Each of these five samples was treated as individual materials.

Fuel samples were selected to simulate possible worst case conditions through their compositional design, e.g., their high aromatic hydrocarbon concentrations and high sulfur content. Fuels used in this work included:

- **JP-8**, from Howell Hydrocarbons, AL-18136.
- **MIL-F-46162B** referee grade diesel fuel from Sun Oil, AL-12329.
- **MIL-F-46162C** referee grade diesel fuel by Howell Hydrocarbons, AL-18135.
- **MIL-F-53080, Type II** engine reference fuel, AL-14751.
- **Middle distillate fuel simulant**, a blend of model compounds.

The procured JP-8 was specified to contain close to the maximum allowable concentration of 25 vol% of aromatic hydrocarbons.

Two samples of MIL-F-46162 referee grade diesel fuels were procured, one from each of two sources. These marginal quality 1-percent sulfur-containing fuels were designed as "worst case" diesel fuels to be used in research, development, and proof testing of compression ignition engines and other equipment that are to operate with tactical grades of diesel fuels conforming to VV-F-800 specifications. The fuel coded AL-12329 is claimed to contain the FOA-15 additive package, while diesel fuel AL-18135 was ordered to contain the MIL-S-53021 stabilizer additive package. Additionally, since the requirement for fuel system icing inhibitor (FSII) became part of the fuel specification used for the procurement in the development of new collapsible fuel-tank materials, it was specified that this fuel should contain the maximum allowable concentrations of ethyleneglycol monomethyl ether.

The Type II referee fuel, described in MIL-F-53080, AL-14751, was included in the experimental matrix because such low quality, low volatility fuel is anticipated to be marketed in the 1990-2025 time frame. This fuel is specified by TACOM to be used by developers of Army multifuel engine combustion systems.

A blend of model compounds was also prepared to serve as a reproducible quality middle distillate fuel simulant. This fuel simulant was designed to have chemical composition and physical properties (e.g., density, boiling range) that may mimic both diesel fuel and JP-8. Initially, this fuel simulant contained about 40 vol% of aromatic hydrocarbons in saturated aliphatic and alicyclic hydrocarbons. Additionally, this mixture also contained di-t-butyl disulfide to provide 1 wt% of sulfur in the blend, FSII additive, and a cetane number improver. The specific composition of this tentative middle distillate fuel simulant is:

<u>Compound</u>	<u>vol%</u>	<u>wt%</u>
dodecane	18.4	16.65
hexadecane	18.4	16.15
decahydronaphthalene	20.0	20.97
tetrahydronaphthalene	20.0	22.77
i-butyl benzene	20.0	19.97
di-t-butyl disulfide	2.5	2.72
octyl nitrate	0.5	0.57
ethyleneglycol monomethyl ether	0.2	0.20

Specification type analysis of the four fuels and the fuel simulant are summarized in TABLE 1.

B. Experimental Details

It was claimed that all products except Elastomer A were identical on both of their surfaces, i.e., the compositions of the "inside" and "outside" coatings were the same. Since, however, spills may occur in actual field use, it was considered unrealistic to expect that fuel would not contaminate the outside of fuel tanks. For this reason, preferential exposure of the individual elastomers was avoided. Similarly, the cut edges of the elastomers were not sealed, but they were allowed to remain exposed. Such exposure sites were expected to show the accelerated effects of internal wicking and seepage through possible damages in the coatings of the fabrics.

Accelerated compatibility evaluations of the fuels and elastomers were performed in a matrix of experiments in which all single combinations of fuels and elastomers were surveyed, i.e., each elastomer was exposed to each fuel. Control (blank) experiments provided baseline data. This accelerated exposure was carried out at 80°C for 14 days. To alleviate the effects of oxidative and photo-induced degradation of components, all the experiments were carried out in amber borosilicate bottles under the inert atmosphere of argon.

The elastomers were cut into approximately 15 mm by 100 mm slices. In case of the seams, the sample included the entire width of the seam. To provide for replicate sampling, three pieces of the same elastomer were placed into each bottle that contained 200 mL of argon-purged fuel, and two such bottles were used for each fuel-elastomer combination. The inerted

TABLE 1. Analysis of Fuels

Property	Method	MIL-F-46162B	MIL-F-46162C	JP-8	Type II	Fuel Simulant
		(Sun) AL-12329-F	(Howell) AL-18135-F	(Howell) AL-18136-F	MIL-F-53080 AL-14751-F	
Gravity, °API at 15°C	D 1298	34.3	29.4	45.8	24.8	34.1
Density, kg/L at 15°C	D 1298	0.8530	0.8790	0.7977	0.9048	0.8540
Color	D 1500	L5.0	3.0	L0.5	3.0	L0.5
Flash Point, PMCC, °C	D 93	62	77	47	83	--
Cloud Point, °C	D 2500	-26	<-42	<-50	-19	--
Pour Point, °C	D 97	-33	<-42	<-50	-25	--
Freezing Point, °C	D 2386	-2	<-48	<-57	--	--
Smoke Point, mm	D 1322	--	12.8	19.7	--	--
Kinematic Viscosity, cSt, at 40°C	D 445	2.14	3.24	1.03	6.99	--
Distillation, °C	D 86					
Initial Boiling Point		174	193	164	196	172
10% Recovered		200	220	173	231	189
50% Recovered		241	273	182	314	199
90% Recovered		326	332	199	385	268
End Point		363	368	211	>404	281
Recovered, vol%		99.0	99.0	99.5	93 at 404°C	99.5
Residue, vol%		1.0	1.0	0.5	--	0.5
Ash, wt%	D 482	<0.01	0.01	--	<0.01	--
Carbon Residue, 10%						
Bottoms, wt%	D 524	0.16	0.14	0.08	0.15	--
Particulate Contamination, mg/L	D 2276	2.1	10.0	0.8	6.5	--
Accelerated Stability, mg/100 mL	D 2274	0.3	0.6	0.3	0.6	0.8
Existent Gum, mg/100 mL	D 381	17.0	8.9	0.7	103.5	12.3
Thermal Stability, JFTOT, Visual	D 3241	--	--	4	>4 Peacock	>4 Peacock
Neutralization No., mg KOH/g	D 664	0.02	0.24	<0.01	--	--
Copper Strip Corrosion	D 130	1A	1A	1A	--	--
Electrical Conductivity, pS/m	D 2624	200	150	0	--	--
Carbon, wt%		86.19	86.54	85.85	86.75	86.44
Hydrogen, wt%		12.66	12.47	13.66	12.26	12.24
Sulfur, wt%		1.00	1.00	<0.01	0.92	1.01
Water, ppm	D 1744	114	152	80	106	58
FSII as EGMME, vol%	FTM 5340	0.01	0.15	0.11	0.00	--
Aromatics, vol%	D 1319	33.8	48.3	24.6	56.2	43.5
Aromatics, wt%	HPLC	25.6	28.2	27.0	29.0	35.3
Saturates, wt%	HPLC	74.4	71.8	73.0	71.0	64.7
Aromatic Ring Carbon, wt%	UV					
Mononuclear		8.6	12.3	15.8	13.3	20.0
Dinuclear		10.9	6.8	1.5	4.2	0.2
Trinuclear		1.4	0.7	0.1	0.7	0.1
Total		20.9	19.8	17.4	18.2	20.3
Peroxide No., ppm	D 3703	6	3	0	10	188
Heat of Combustion, Net,	D 240					
Btu/lb		18,223	18,052	18,338	--	--
MJ/kg		42.39	41.99	42.65	--	--
Cetane Number	D 613	48	44	39	40.2	--
Cetane Index	--	40	40	37	39.3	24.4

bottles were sealed with Teflon[®]-lined screw caps. The bottles were then placed for 14 days in an explosion-proof, electrically heated oven, whose temperature was controlled at $80 \pm 1^\circ\text{C}$.

After 14 days of exposure, the bottles were removed from the oven, and they were allowed to cool overnight to room temperature. The elastomer specimen were retrieved from the fuels, rinsed with hexane, and allowed to air dry.

Effects of the $80^\circ\text{C}/14$ -day exposure were evaluated by comparing the changes that took place in the fuels and in the elastomers during the experiments. Changes in the fuels were followed by examination of their infrared (IR) and differential infrared (DIR) spectra, measurement of their color change, and determination of their gum and water contents. Chemical changes at the surface of the elastomers were followed by Fourier transform infrared (FTIR) spectroscopy, while their physical changes were evaluated by visual examination, by hardness measurements and by photomicrographs. Where appropriate, the arithmetic average of the experimental results will be presented.

III. RESULTS AND DISCUSSION

A. Effects of Fuels on Elastomers

1. Visual Effects

Elastomer A: Heating of this elastomer for 14 days at 80°C without fuel produced no noticeable effects. Fuel AL-18136 (JP-8) and the fuel simulant introduced some surface dulling effects, and increased stiffness. The heavier referee grade diesel fuels did not seem to affect this elastomer.

Elastomer B: Heating alone did not affect this product. With the exception of the darker colored AL-14751, all the fuels and the fuel simulant produced shiny surfaces. The fuel simulant and the JP-8 also caused slight curling of this elastomer.

Elastomer C: This elastomer is the seam section of Elastomer B. It became considerably stiffer due to heat alone. When it was heated in the presence of fuels and the fuel simulant, then allowed to cool and dry, the elastomers's surfaces became shiny and less flexible.

Elastomer D: Heating this product in the absence of fuel caused no observable effects. All the fuels caused an increase in sample stiffness and increased definition of the fabric's woven pattern.

Elastomer E: This seam section behaved essentially identically to Elastomer D, but a whitish film that resisted rubbing off was noted on the surfaces.

2. Photomicrographs

Comparisons of the various virgin and exposed elastomers were made through an optical microscope at magnifications ranging from 10× to 1000×. It was expected that these observations may be used to augment the normal visual observations. None of the photomicrographs, however, produced useful information.

3. Elastomer Hardness

Changes in elastomer hardness were determined by ASTM Standard Test Method for Rubber Property-Durometer Hardness, D 2240-86, using a Shore Type A-2 durometer. This method was selected because of its simplicity and speed. It must be stressed, however, that the results may only be used as approximations, because, according to ASTM, "this test method is not recommended to the testing of coated fabrics," and also because the method specifies that "the test specimen shall be at least 6 mm (0.25 in.) in thickness unless it is known that identical results are obtained with thinner specimen."

It was found, however, that on all the elastomer-coated fabrics of this project the measured hardnesses were within experimental error regardless of where the probe was placed on the elastomer, i.e., over an elastomer-coated thread or between the threads of the fabric. The thickness criterion was only met by Elastomer A. When durometer readings were taken of

multiple layers of the thinner Elastomers B through E, the results were never over 2 hardness units, each unit corresponding to indentations by the durometer's indenter of less than 0.001 inches, or 0.0254 mm. It was argued, therefore, that the procedure may be used to approximate the hardness of the elastomers used in this project.

Two sets of hardness readings were taken. The first set of data was obtained within two days after the specimens were removed from the fuels, were hexane washed, and were allowed to dry. The second set of measurements were taken after 6 weeks of drying time. The arithmetic averages of the replicate readings are summarized in TABLE 2. The same data are graphically shown in Figs. 1 and 2.

In the bar charts of Figs. 1 and 2, six sets of results are shown. Sets "A(a)" and set "A(b)" refer to data measured at the inner and outer surfaces of Elastomer A. Sets B through E depict the data obtained from Elastomers B through E, respectively. Within each set of bar graphs, each bar shows the hardness data corresponding to those obtained from the elastomer sample heated in the absence of any fuel, i.e., the blank sample, and the data that resulted from the appropriate elastomer heated under the four fuels, and the fuel simulant. The measurements showed that, as indicated by the manufacturers, each elastomer pair (B through E) had identical surfaces on both sides, i.e., they did not have individual coatings that were designed specifically to contain hydrocarbons or to be resistant to the elements.

TABLE 2. Effect of Fuel on Elastomer Hardness (Shore Type A-2 Durometer)

Elastomer	Identification No. Fuel	Drying Time	
		2 Days	6 Weeks
A(a)	18136	64	69
A(b)	18136	73	82
B	18136	95	96
C	18136	94	95
D	18136	97	96
E	18136	96	97
A(a)	12329	62	65
A(b)	12329	70	75
B	12329	95	96
C	12329	94	94
D	12329	97	97
E	12329	95	97
A(a)	18135	62	67
A(b)	18135	71	75
B	18135	95	97
C	18135	95	94
D	18135	97	98
E	18135	95	96
A(a)	14751	64	66
A(b)	14751	73	75
B	14751	96	97
C	14751	95	94
D	14751	97	97
E	14751	96	97
A(a)	Simulant	62	66
A(b)	Simulant	71	81
B	Simulant	95	97
C	Simulant	95	95
D	Simulant	97	97
E	Simulant	96	95

Notes:
(a)=Inner surface.
(b)=Outer surface.

It is obvious that the hardness of the tested elastomers has changed little due to heat and that this measurement did not change appreciably when the elastomers were heated in the presence

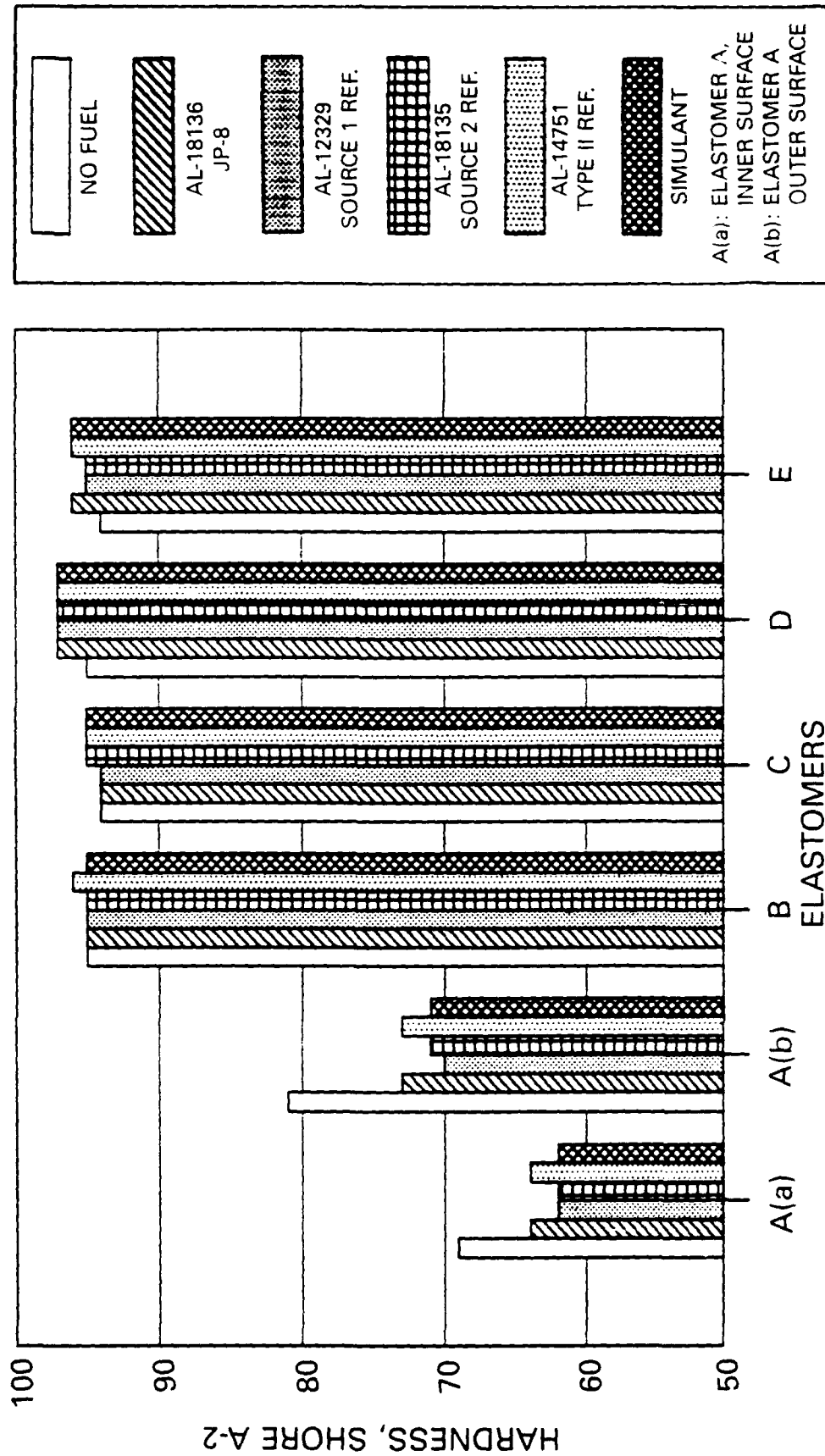


Figure 1. Effect of fuels on elastomer hardness 2 days after exposure

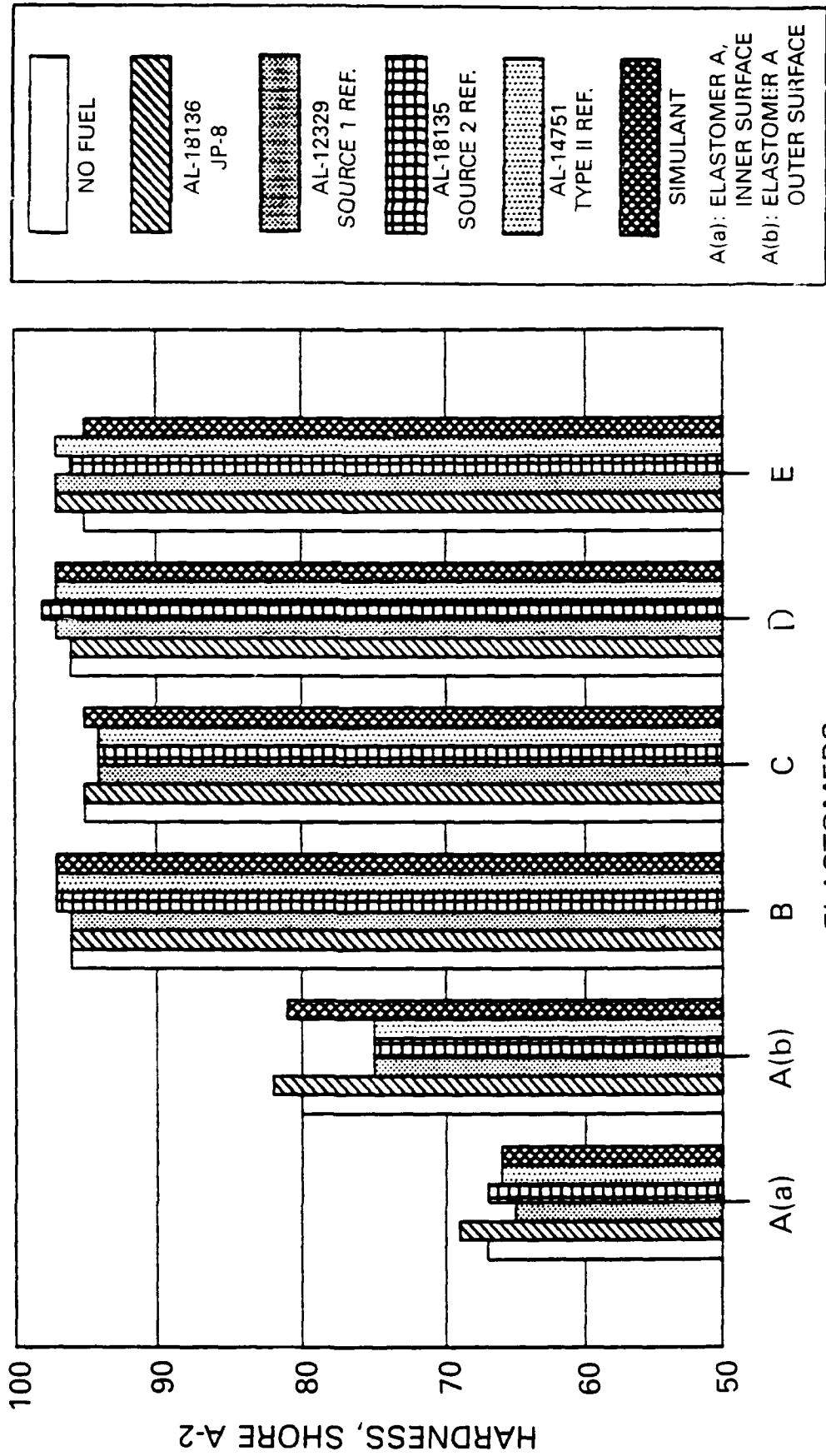


Figure 2. Effect of fuels on elastomer hardness 6 weeks after exposure

of the fuels. The increased hardness of the elastomers after 6 weeks of drying time after the exposure is documented. As their design indicates, only Elastomer A gave different hardness readings at its two surfaces, and this product also was considerably softer than the rest of the products. These data also suggest that Elastomer A is more sensitive to exposure to fuels on the "wrong," i.e., its outside surfaces, than the other elastomers. Hardness of the other products did not show special sensitivity to any of the fuels.

4. FTIR Spectroscopy

Chemical changes at the surfaces of the elastomers were monitored by Fourier transform infrared spectroscopy (FTIR), using attenuated total reflectance (ATR) techniques on a Digilab FTS-15 spectrometer equipped with a 3240 data system. The spectra of Elastomer A samples were made using a germanium ATR crystal, while the other elastomers' spectra were obtained on a KRS-5 ATR crystal.

Individual FTIR spectra were obtained on the "as received" elastomer samples to serve as base line. FTIR spectra of samples that were heated at 80°C/14 days without the fuels were developed to be used as controls (blanks) in the comparative evaluations with those spectra that were obtained on those samples that were similarly heated in the presence of the fuels. Differential FTIR's were generated by subtracting the spectrum of the blank from that derived from the corresponding fully exposed elastomer.

All the elastomers, with the possible exception of Elastomer D, seemed to contain talc (probably magnesium silicate) at their surfaces, as indicated by absorbance bands at wavenumbers centered around 3680, 1075, 1020, and 670 cm^{-1} . It may also be concluded that, according to FTIR, all the fuels and the fuel simulant produced essentially similar results.

Examination of the differential FTIR spectra of the individual elastomers lead to the following conclusions:

In the case of Elastomer A, there are indications that, during heating even without fuels, some aromatic hydrocarbons may have migrated to the surface, as suggested by bands at 3040 to 3060, 1580, 1610 and at 1515 cm^{-1} . Additionally, the fuel-soaked samples appeared

to contain more amide-type material, as evidenced by absorbance bands at 3300, 1640, and 1540 cm^{-1} wavenumbers.

Elastomers B and C, upon exposure, showed only very small changes at their surfaces, according to FTIR. A small absorbance band at around 2170 cm^{-1} was evidence for the presence of some cumulative bonds, e.g., unreacted isocyanates, nitriles, etc., in all these samples. The intensity of these bands decreased upon heating both in the absence and in the presence of fuels. This observation suggests that some of the unreacted isocyanates, one of the starting materials of all of these elastomers, may have been present in these products, and that these compounds underwent continued reactions or may have evaporated due to heat.

Substantial changes were induced by the exposure in the carbonyl region of Elastomers D and E. When the FTIR spectrum of a heated elastomer was subtracted from that of the corresponding elastomer that was heated in the presence of a fuel, an essentially complete "negative absorbance" spectrum of a carbonyl compound was obtained, exhibiting a strong band at around 1727 cm^{-1} . This observation is probably due to the loss of a plasticizer during the exposure. This explanation is supported by the results of the previously noted visual observations, i.e., these elastomers became stiffer after their exposure to heated fuels.

An example of such a differential FTIR spectrum is shown in Fig. 3. This spectrum was generated by the subtraction of the spectrum of the heated Elastomer D from that arising after heating it in the presence of the MIL-F-46162C referee grade diesel fuel, AL-18135. This differential spectrum closely resembles the spectrum (from the Library of Sadler Research Laboratories) of a widely used plasticizer, dioctyl phthalate, whose spectrum is presented as Fig. 4.

B. Effects of Elastomers on Fuels

1. Visual Effects

Fuel No. 18136 (JP-8): This fuel is essentially colorless. After exposure to heat in the presence of Elastomers A, D, and E, formation of a whitish precipitate was noted.

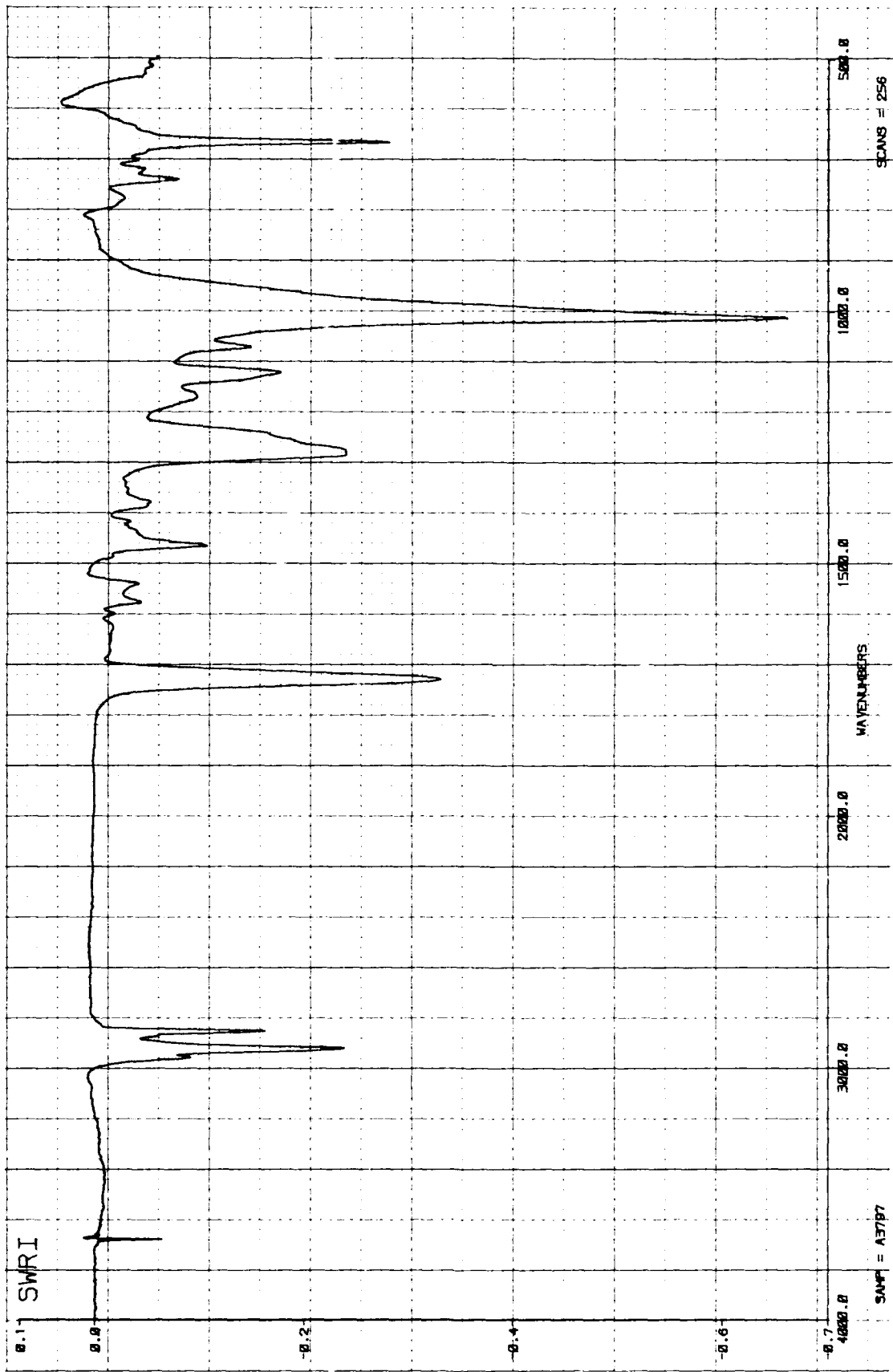


Figure 3. Differential FTIR spectrum of heated and fuel-exposed Elastomer D versus the heated Elastomer D

CONDENSED PHASE

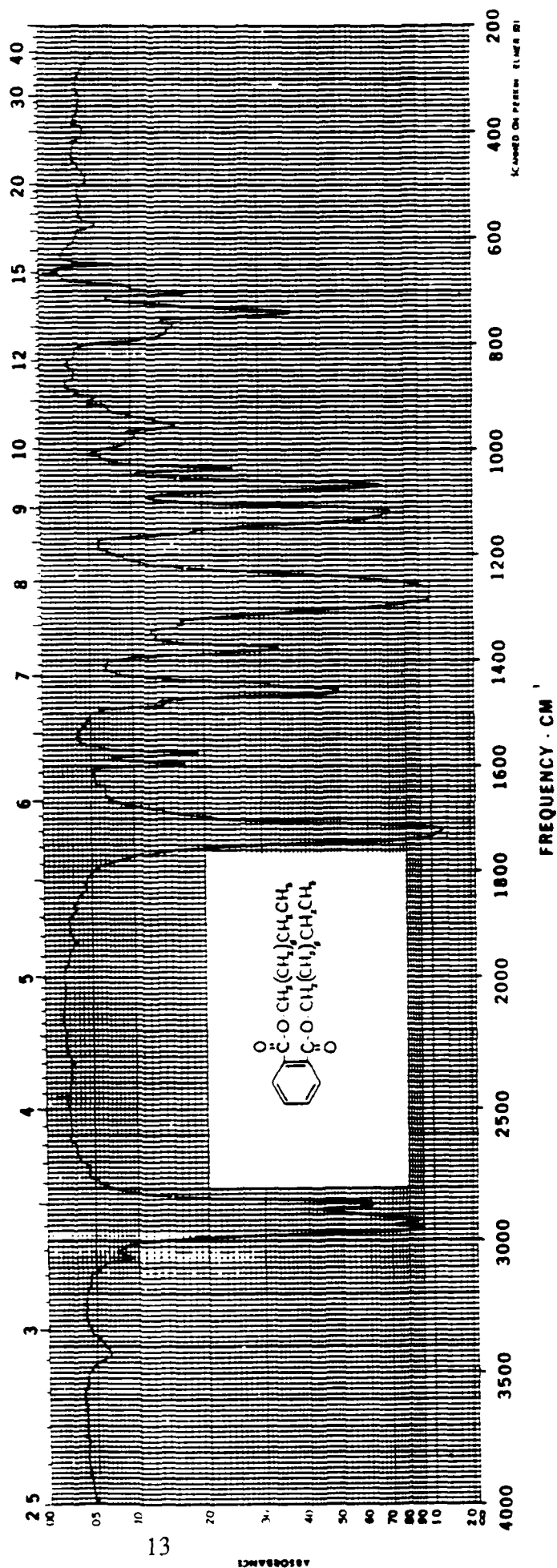


Figure 4. Infrared spectrum of dioctyl phthalate

Fuel No. 12329 (MIL-F-46162B): After exposure to heat in the presence of Elastomers A, D, and E, formation of a precipitate was noted.

Fuel No. 18135 (MIL-F-46162C): Considerable amounts of grayish substance precipitated in case of Elastomer A. Slight amounts of precipitates were noted in case of Elastomers D and E.

Fuel No. 14751 (MIL-F-53080, Type II): Heating of this fuel even without an elastomer caused the formation of a dark-brown sediment. As above, Elastomer A caused the precipitation of copious amounts of grayish material. Heating of this fuel in the presence of Elastomers D and E produced smaller quantities of brownish precipitate.

The Fuel Simulant: This colorless blend of model compounds was designed to have chemical composition and physical constants (e.g., density and boiling range) that may mimic both diesel fuels and JP-8. During these elastomer compatibility experiments, it was found that there was less interference by fuel component degradation products to the evaluation of the results by these colorless products than by the darker colored diesel fuels. In this respect, the blend of model compounds behaved similarly to JP-8.

As in the case of the JP-8, Elastomer A imparted some brownish coloration to the blend, and whitish deposit formation was noted when exposed to Elastomers A, D, and E.

2. Infrared Spectroscopy

Infrared and differential infrared spectroscopy did not provide substantial information on the supernatant fuels' contamination due to their exposure to the elastomers. This observation is probably due to the fact that the concentrations of contaminants were below the detectability limit of the instrumentation. Centrifuging the Elastomer A exposed fuels at 1500 rpm for 30 minutes separated bottom layers that were examined by IR and differential IR techniques. In each case, the bottom layers exhibited large and well-defined absorbance peaks centered around 3290, 1740, 1635, 1535, 1462, and 1250 cm^{-1} . The information suggests that amines, esters, carbamates, amides, silicates (probably from the magnesium silicate talc) and silicones were

leached out from this product by each fuel, thus contaminating the fuel. (These contaminants may have originated from the "outer" surfaces that were not intended to be fuel resistant.)

3. Fuel Properties

The effects of the elastomers on fuel properties are demonstrated by changes in the fuels' color, gum, and water contents. These data are summarized in TABLE 3. The same data are graphically illustrated in Figs. 5 through 8. In each case data are given for the neat, unaltered fuel, for the fuel that was heated without elastomer, and finally, for the fully exposed fuel, i.e., the fuel that was heated together with the appropriate elastomer.

a. Color Changes

The fuels' color changes, as measured according to ASTM D 1500, are shown in Fig. 5. Each of the three diesel fuels became substantially darker due to heat alone, and they did not show usable discrimination among the products. Results from exposures under JP-8 and the fuel simulant ran parallel. The data indicate that these clear, lighter fuels extracted components from Elastomer A, and became appreciably darker, thereby providing a measure of discrimination.

b. Gum Content

The measured data, as obtained through the "steam jet gum" procedure of ASTM D 381, are shown in Figs. 6 and 7. Identical data are given in both of these figures, but expanded

TABLE 3. Effect of Elastomers on Fuel Properties

Identification No.		Property		
Elastomer	Fuel	Gum, Mg/100 mL	Water, ppm	ASTM Color
--	18136(a)	0.7	80	L0.5
--	18136(b)	0.2	43	0.5
A	18136	55.4	99	1.5
B	18136	4.6	58	0.5
C	18136	12.6	58	0.5
D	18136	21.9	56	0.5
E	18136	56.4	76	0.5
--	12329(a)	17.0	114	5.0
--	12329(b)	20.1	55	5.0
A	12329	93.4	80	5.0
B	12329	40.8	87	5.0
C	12329	39.4	71	5.0
D	12329	56.8	89	5.0
E	12329	75.5	73	4.5
--	18135(a)	8.9	152	3.0
--	18135(b)	9.4	99	3.5
A	18135	90.3	172	5.0
B	18135	13.6	109	3.5
C	18135	20.4	102	3.5
D	18135	31.1	110	3.5
E	18135	62.5	113	3.0
--	14751(a)	103.5	106	3.5
--	14751(b)	82.4	82	5.0
A	14751	639.8	196	5.0
B	14751	136.8	112	4.5
C	14751	227.1	88	4.5
D	14751	141.8	97	4.5
E	14751	180.6	100	4.0
--	Simulant(a)	12.3	58	L0.5
--	Simulant(b)	16.1	85	0.5
A	Simulant	92.3	101	2.0
B	Simulant	21.2	86	L0.5
C	Simulant	45.0	85	L0.5
D	Simulant	48.3	77	0.5
E	Simulant	92.2	88	0.5

Notes:

(a)=Unaltered neat fuel.

(b)=Fuel heated without elastomer.

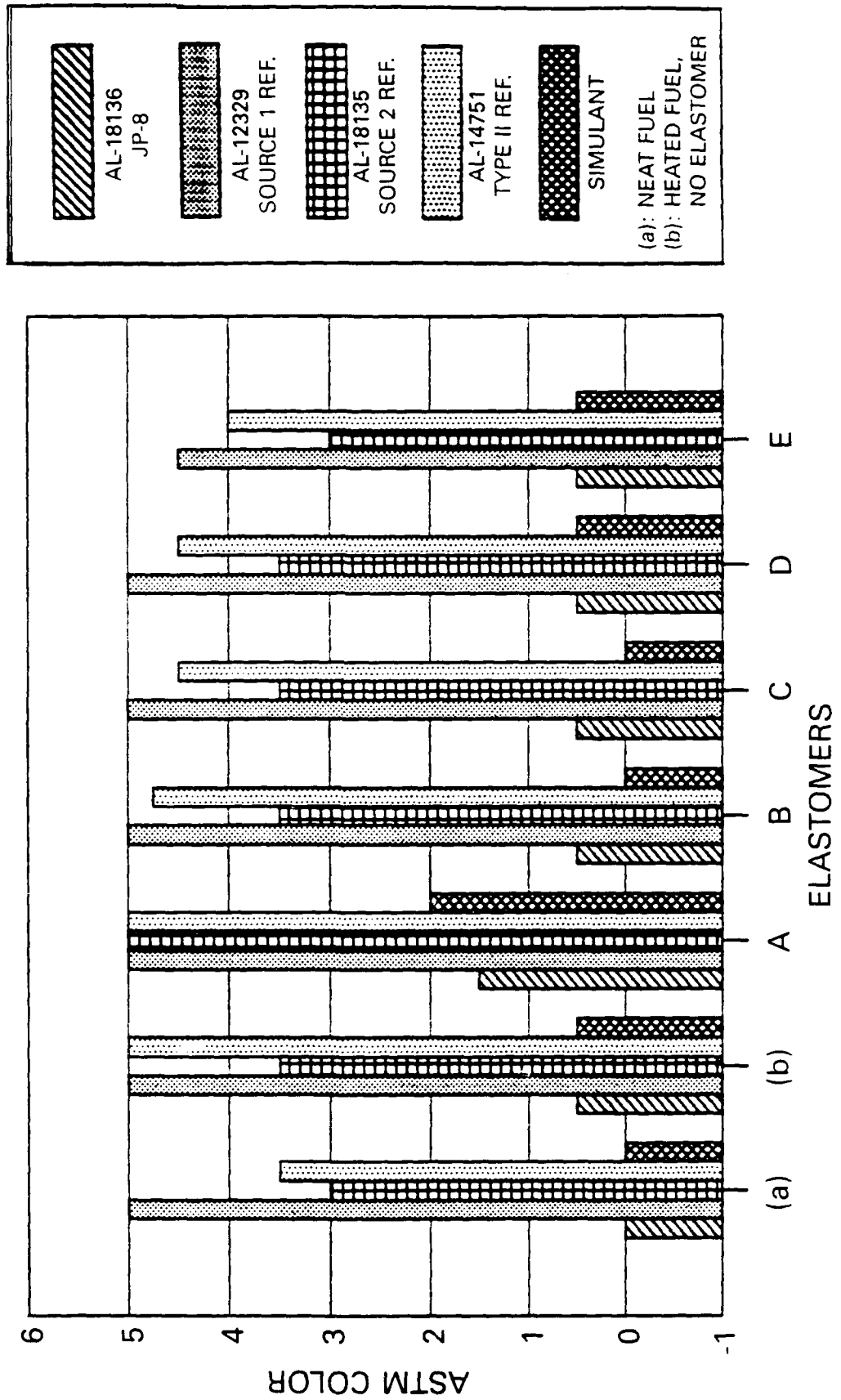


Figure 5. Influence of elastomers on fuel color

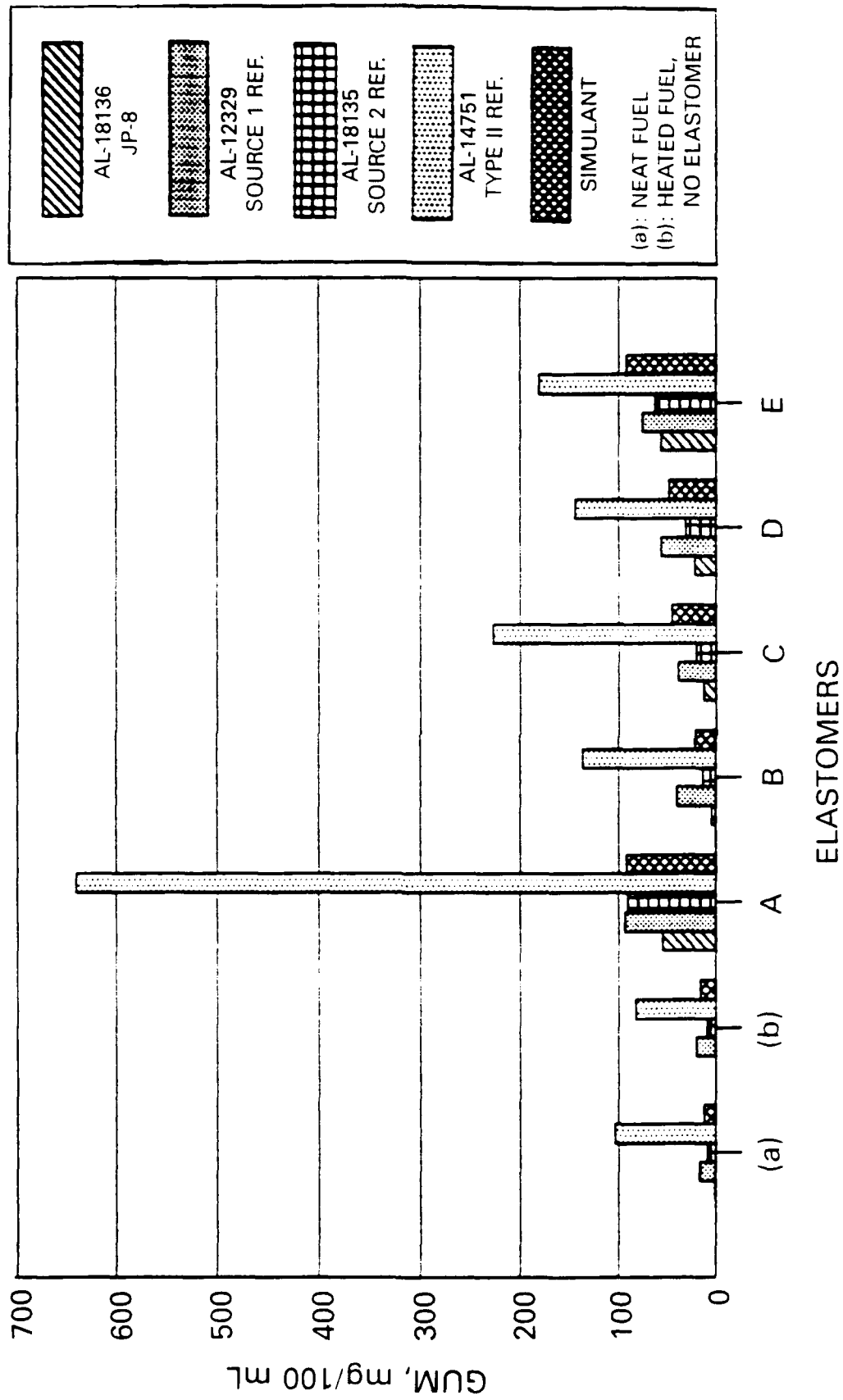


Figure 6. Influence of elastomers on gum content of fuel

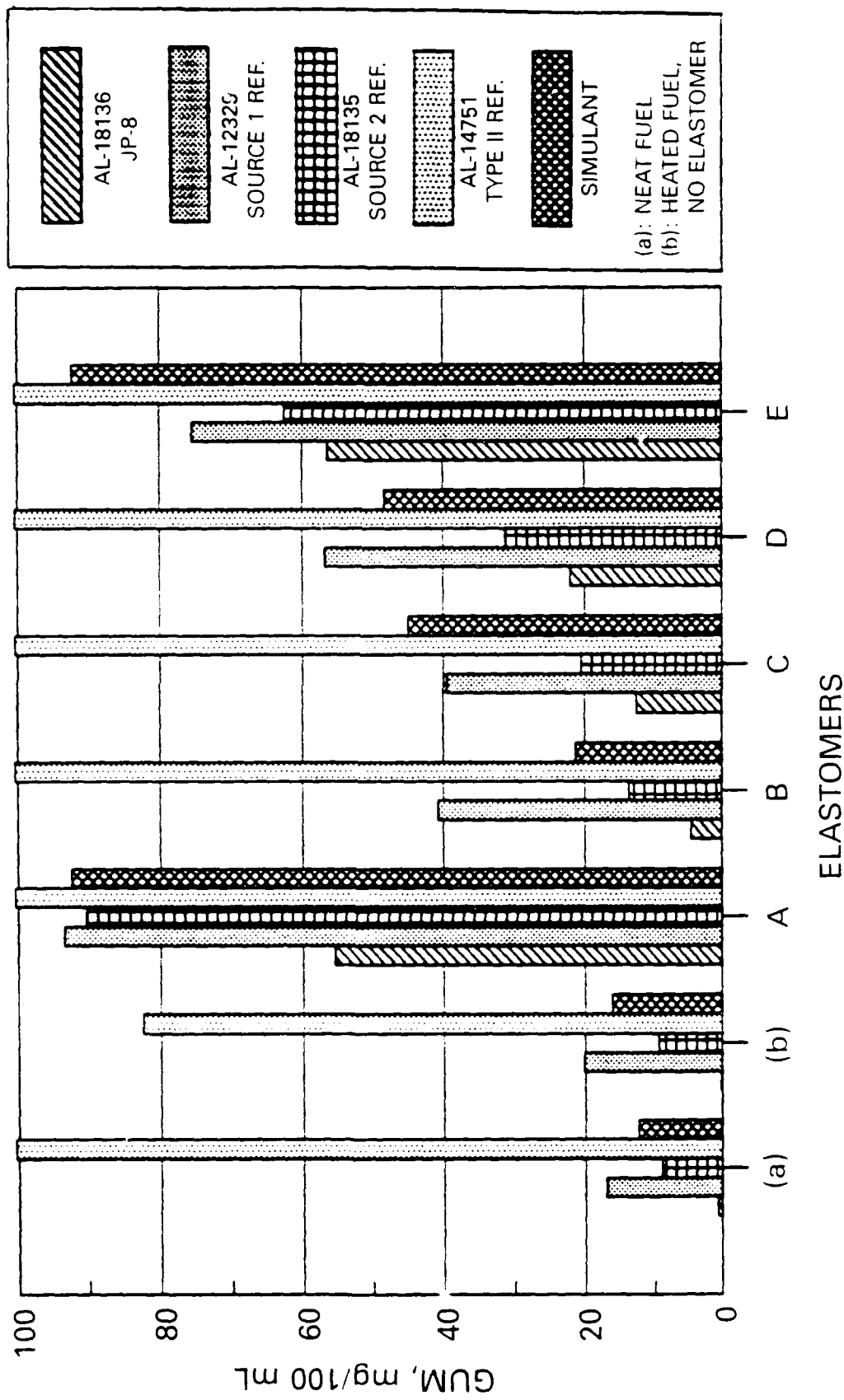


Figure 7. Influence of elastomers on gum content of fuel (expanded scale)

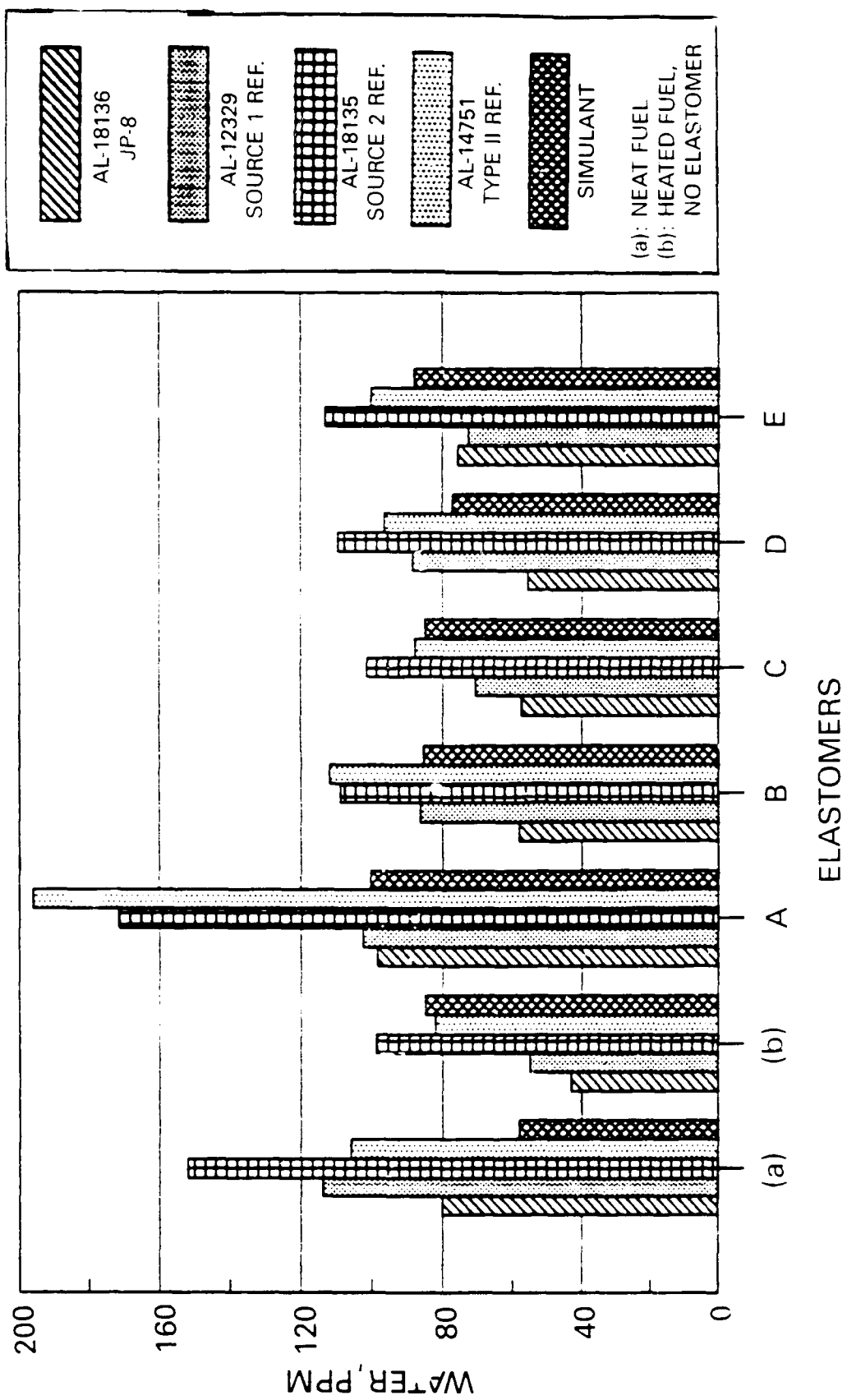


Figure 8. Influence of elastomers on water content of fuel

scale is used in the later. The high instability of the MIL-F-53080, Type II fuel is obvious. Again, each fuel extracted substantial quantities of components from Elastomer A. The three heaviest fuels gave variable results, while the results of the JP-8 and the fuel simulant-exposed products gave a tighter grouping of data. These two fuels gave consistent results, with the JP-8 giving lower (more optimistic) results than the fuel simulant.

It is of interest to compare the results obtained with elastomer pair B and C, and elastomer pair D and E. In both cases, the seam sections, Elastomers C and E, gave higher gum values than the wall sections, Elastomers B and D.

c. Water Content

These data, shown in Fig. 8, do not offer a discriminating tool for the evaluation of middle distillate fuel and elastomer interactions within the limits of these experiments.

IV. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Five collapsible, elastomer-coated fabric products were exposed to four middle distillate fuels and to a middle distillate fuel simulant. The coated fabrics were represented by a drum material, a pillow tank fabric and its seam section, and a berm liner with its seam section. Each of these samples was treated as individual material.

Compatibility of these products was studied under accelerated conditions, during which each elastomer was submerged in each fuel for 14 days at 80°C.

The effects of the fuels on the elastomers and the effects of the elastomers on the fuels were evaluated using visual observations, photomicrographs, infrared spectroscopy, and measurement of hardness, color, gum, and water contents.

Under the experimental conditions, Elastomer A had the most dramatic effects on the fuels. The fuels became substantially darker and developed increased gum contents. Elastomer pair B and C gave indications that they contained unreacted isocyanates, which continued to react

under the exposure conditions of these studies. The fuels and the fuel simulant extracted a plasticizer from Elastomer pair D and E. The presence of talc, used to prevent unwanted adherence of layers of the elastomers, was detected. Although indications were that this talc may have contaminated the fuels, this possibility was not proven.

The Type II referee fuel of MIL-F-53080 specification was the most reactive of the fuels. It developed large quantities of gums. The two MIL-F-46162 referee grade diesel fuels gave more "reasonable" results and behaved similarly. The clear, lighter JP-8 and the fuel simulant became substantially darker when exposed to Elastomer A, thus yielding a higher degree of discrimination than the darker, heavier fuels. The JP-8 and fuel simulant gave essentially identical results, with the JP-8 giving somewhat lower, i.e., more optimistic results, than the fuel simulant. This observation may be due to the higher aromatic hydrocarbon content of the fuel simulant when compared with the JP-8.

The FTIR results and the increased stiffness of the two exposed elastomer pairs indicated that some of the plasticizer(s) were leached out of their coatings by the fuels. The effects of these extracted components on the fuel quality is unknown at this time. Modification of elastomer formulation may alleviate this problem.

Berm liners are used to protect the soil from spillage from their associated tanks. As a result, the berm liners should be resistant not only to the atmospheric elements, e.g., moisture, UV-radiation, but should also be resistant to fuel components. If the fuel-extracted plasticizer reduces the long-term integrity and usefulness of these products, then the composition of the liners should also be modified.

The detrimental effects of fuel spillage on the outer surfaces of coated-fabric tanks may be alleviated by providing hydrocarbon-resistant coating not only to the inner, but also to the outer surfaces.

Use of the tentative middle distillate fuel simulant led to conclusions similar to, but marginally more severe, than those obtained through the use of JP-8. Refinement of this composition may be achieved in the future. It is also recommended that a second repeatable quality fuel simulant composition be developed that would more closely mimic the influence of diesel

fuels. Such a product may also be used in the qualification specifications of elastomeric fuel-handling materials to be used with diesel fuels.

It has been shown (1-3)* that the concentration of aromatic hydrocarbons in JP-5 and JP-8 vary from 4 to 25 vol%. The effects of fuels containing increased concentrations of aromatic hydrocarbons were demonstrated in this study. Further detailed investigation of the effects of varied aromatic hydrocarbon concentrations in both turbine and diesel fuels on elastomeric components is warranted. This investigation should also include the effects of cyclic exposure of elastomeric components to fuels of varied composition. Additionally, performance and compatibility of newly developed elastomers should be monitored and investigated.

Cursory investigations (4) correlated the combined concentrations of certain low molecular weight aromatic hydrocarbons with elastomer behavior. This observation should be expanded, and also other compound classes should be included in correlating fuels' composition with their performance and compatibility with fuel-handling equipment.

It was shown earlier (5) that certain middle distillate fuels have pronounced effects on certain elastomeric fuel tank materials. Investigation of the effects of fuel composition on the fuels performance and equipment compatibility would be strongly aided by the knowledge that may be gained from the isolation and identification of the fuel components responsible for incompatibility with fielded elastomers. In addition, such knowledge may lead to the development of improved collapsible, coated-fabric fuel-handling materials.

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

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