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## RESEARCH, DEVELOPMENT AND ENGINEERING DIRECTORATE

U. S. ARMY WEAPONS COMMAND

TECHNICAL REPORT

SWERR-TR-72-65

LIQUID POLYMERS AS COATINGS FOR IMPROVED COATED FABRICS (Supplement to RE-TR-71-57)

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## ABSTRACT

Results are presented for the second years' effort of a two-year program initiated by personnel of the Research Directorate, Weapons Laboratory, WECOM concerning the use of liquid polymers as coatings for fibrous and nonfibrous substrates to provide improved weapon accessories such as gun covers and cleaning kit packets. Both pigmented and nonpigmented coatings were investigated.

Application of solvent-diluted polymer coatings to woven substrates caused a significant loss in cross-direction breaking strength.

Base or tie coats (consisting of liquid diamines applied to the substrate prior to application of liquid polymers) did not significantly improve the tear strength of the coated fabrics made from either woven or nonwoven substrates.

Except for the Estane solution coating, the polyurethane liquid polymers were generally resistant to a hydrocarbon fuel, lubricating oil, and insect repellent.

Six months' open sunlight aging in Panama was generally more severe than rain forest aging on both the pigmented and nonpigmented coated fabrics.

The best combination of breaking and tear strength and resistance to accelerated aging was obtained with either a pigmented or nonpigmented liquid polyurethane coated on a Betaglass/Dynel substrate. These experimental materials had abrasion resistance equal to or better than that of the viny! control and two to three times better than that of the neoprene control. The black pigmented material suffered little or no loss in tear strength after accelerated aging while the control materials lost 10 to 20 per cent in tear strength.

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## OBJECTIVE

The objective of the program was to investigate the use of liquid polymers as coatings for fabrics to meet specific Army weapon system needs, including flexibility at low temperatures, resistance to abrasion and, good environmental stability.

## BACKGROUND

Coated fabrics are used in a wide variety of Army applications such as tarpaulins, gun covers, helicopter covers, pneumatic floating equipment, aircraft protectors, air supported shelters, gun shield mantle covers and fuel storage containers.

The bulk of these coated fabrics is prepared by application of solid rubber or rubberlike coatings to various substrate fabrics. The largest volume of commercial coated fabrics is in the area of coated polyvinyl chloride materials.<sup>4</sup>,<sup>2</sup> Industry primarily supplies neoprene and vinyl coated fabrics to the inj.

Although stisfercover for most civilian needs, current industrial coaters for do not meet these specialized requirements of the million for flexibility at low temperature, abrasion resistance, and fungus resistance.

Liquid polymers (polymeric materials fluid at room temperature or readily liquified by the process of heating without causing degradation) with many of these specialized properties are currently available. Liquid polymers are also reportedly superior to the solid materials (i.e., neoprene and vinyl) in several ways. They are normally ready to use as received and need no laborious production workup, little or no solvents are required and, as a result, these liquid polymers exhibit little shrinkage. Despite their many good features, very little effort has been expended by industry, in the use of liquid polymers as fabric coatings

Previous work in this area<sup>3</sup> indicated that laboratory prepared coated fabrics made with liquid polyurethanes had good abrasion, ozone, and low-temperature resistance.

The work reported here was initiated by personnel of the Research Directorate, Weapons Laboratory, WECOM, and is a continuing investigation of the feasibility of the use of "liquid" polymers as coatings for fitrous substrates to obtain improved coated-fabrics.

## APPROACH

As previously reported,<sup>3</sup> the liquid polyurethane materials were the best of the liquid polymers tested. For this reason, only polyurethanes were investigated during this second year's activity.

The liquid polymers and fibrous substrates obtained for laboratory fabrication of coated fabrics are shown in Table I. Two commercial coated-fabrics, i.e., Type II, Class 2 (vinyl) and Type III, Class B (neoprene), meeting the requirements of Specification MIL-C-20696" were used as controls.

A solid (resinous) polyurethane (Estane 5714 F-1) was included in the test program for comparison purposes. Two of the liquid polymers were semisolid at room temperature.

From 15 to 20 techniques are used to coat various textile materials, the two most often used are the knife and the roller coating techniques. The only laboratory bench coater (of the reverse roll type) available at this Directorate was not adaptable for use with the various viscosities of coating materials utilized, i.e., the very thin, watery Chemglaze material did not adhere to the rolls and the viscous Adiprene material was too tacky. In light of the above, dip coating was used since it was adaptable in all cases.

The following procedures were used to dip coat the polymers invistigated:

<u>Vibrathane B-602 and B-605</u>. These polyether urethanes are solid in the as-received state. Used in the molten condition, they yielded extremely thick coatings. When diluted to 50 per cent solids with toluene, the polymer solution could be used at room temperature. Since most urethanes can be partially cured by reaction with moisture, pieces of the substrate materials (15 by 30 inches) were dip-coated in the polymer solution, by the method indicated in the figure, drained and hung in a controlled atmosphere (73°F, 50 per cent R.H.) for three days. The resultant coatings were tough, smooth, and relatively bubble-free.

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TABLE I

# IDENTIFICATION OF SUBSTRATES AND LIQUID POLYMER COATINGS

<u>Manufacturer</u> Stern and Stern Textiles, Inc. West Point Pepperell Monsanto Co. E.I. Dupont	<u>Manufacturer</u> E.I. Dupont Hughson Chemical Co. Uniroyal Uniroyal B. F. Goodrich Chemical Co.
Trade Name A-2951/6 GV-4030-01 Cerex 5915 Reemay 2011	Trade Name Adiprene L-100 Chemglaze Z004 Vibrathane B-602 Vibrathane B-605 Estane 5714 F-1
Substrate Nylon (open mesh) Betaglass/Dynel Spunbonded Nylon Spunbonded Polyester	- 52

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FIGURE

Dip Coating of Fabrics

urethic coating. Dip coating was the same as that of the B-602 aterial except that no dilution was necessary and the su strates normally required two coats.

Adiprene L-100. This extremely thick molasses-like polyether liquid polymer is normally cured with a diamine First attempts at coating with this polymer indicated that its short potlife (3-i0 minutes), when the recommended diamine curative was used, would not permit the fabrication of the quantity of coated fabric material required for testing purposes. Alsc, the coatings were frequently lumpy. The Adiprene L-100 was dip coated in the same manner as the B-602 material and with the same solvent

An attempt was made to hasten the "moisture" cure-time of the Adiprene and Vibrathane materials with the addition of 0.05 to 0 1 parts of adipic acid. The addition of the adipic acid appeared to decrease the cure time, but the coatings formed contained an excessive amount of bubbles

Estane 5714 F-1 This is a solution grade polyether urethane resin soluble in a variety of solvents including ketones, toluene, tetrahydrofuran (THF), dimethylformamide (DMF), and dimethylsulfoxide (DhSO) The drying rates of the 5714 F-1 resin solutions are dependent upon the solvent used. An approximately 10 per cent solids solution of 5714 F-1 in 70/30 acetone/THF gave the best solution viscosity for dip coating. All substrates received three coats applied in the same manner used with B-602 material except that only one hour of drying time was required between coats.

All resinous coatings were clear and semiglossy. In an effort to obtain ultraviolet light-resistant materials, black pigmented coatings were prepared by addition of five to ten parts per hundred of a 1:1 combination of a fine thermal (FT) carbon black/trioctylphosphate to the various urethane solutions.

Results of the evaluation of coated fabrics described in the previous year's work and aged for six months outdoors in Panama are also included in this investigation.

The test methods used to evaluate the experimental and control coated fabrics are shown in Table II.

## TABLE II

## PROPERTIES DETERMINED AND TEST MET: ODS USED<sup>1</sup>.

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Weight, az./sa.vd.	F.T.M.S.* 191, Method 5041
	F.T.M.S. 191, Method 5030
Breaking Strength. ]b.	F.T.M.S. 191, Method 5102.
Abrasion-Resistance	F.T.M.S. 19], Method 5304 <sup>6</sup>
Low Temperature Flexibility	
Heat Stability	
Fungus Resistance	F.T.H.S. 191, Method 5760
Ozone Resistance	
Chemical Resistance	
Weathering Resistance	F. T.M.S. 191, Method 5804
Tear Resistance	At 4 Method D1004
Hydrolytic Stability	7.

5102 5304<sup>2</sup> 5041 5030

**Method** 

6 \*Federal Test Method Standard

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3. Specimens (: inch by 6 inches) were conditioned for four hours at -67°F and then flexed over a All testing was performed at 73°F and 50% R.H. (Federal Test Method Standard 406, Section 4) unless otherwise indicated in the applicable test 4. Temptrature, pressure, and dwell time were varied on the impulse and thermal heat sealers as Modified as follows: 240-grit paper, 6-pound load, 3.5 pound tension, 1000 cycles. required to obtain proper heat seals. ]/4-1sch mardre]. method

Time 5. Specimens (1 inch by 3 inches) were bent and wrapped around 1/16, 1/8, and 1/4 inch rods and exposed in an ozone chamber maintained at  $100^{\circ}F \pm 2^{\circ}F$  and 50  $\pm 5$  pphm ozone for seven days. Timt to first crack was observed under 7-power magnification.

6. Specimens were 2 inches by 4 inches. Test fluids were MiL-L-46000. Lubricating 011; TT-S-735. Type II Fuel (60/5/20/15 Iso-Octane/Benzene/ Toluene/Xylene); and O-I-503. Type I Insect Re-pellent. The chemical resistance of the coated fabrics was evaluated as follows: one-half of a specimen was covered with a test fluid and the results were observed after 7 days at 73°F and 50 per cent R.H.

7. Specimens 1 inch by 4 inches were suspended over 200 milliliters of distilled water in a tightly sealed one-quart jar. The assembly was placed in an oven maintained at 158°F for 30 days.

## **RESULTS AND DISCUSSION**

## Substrates

The properties of two woven and two nonwoven fabrics, as received from industry, are listed in Table III. The woven nylon material is similar to the base fabric used in MIL-C-20696. This weight of fabric is strong, relatively easy to coat, and has a good hand (drape-flexibility) Although the woven Betaglass fabric is somewhat less flexible and weaker than the nylon material, it is more resistant to the effects of ultraviolet light than nylon (most noticeable in the cross direction, Table III). The nonwoven materials were selected for investigation because of three important characteristics; they are lightweig t, flexible, and inexpensive. The price range of nonwovens is from 20 to 85 cents per square yard for a 5-ounce standard-weave nylon fabric. The overall properties of the spunbonded Cerex nylon were superior to those of the spunbonded Reemay polyester. However, the resistance to deterioration by ultraviolet light was relatively the same for both fabrics.

## Liquid Polymers

The properties of the liquid polymers used to coat the substrates, shown in Table III, are presented in Table IV (unpigmented materials) and Table V (black pigmented materials) The chemical resistance of the coated fabrics is given in Table VI.

The four "liquid" urethane polymers varied widely in viscosity, i.e., from the water-thin Chemglaze to the very thick Adiprene (approximately 30 to 20,000 CPS, respectively, at 77°F) and the extremely thick (semisolid) Vibrathanes The 10 per cent solids solution of the Estane resin in Acetone/THF was approximately the same viscosity as the Chemglaze coating material.

The resin pickup was greatest for the closely woven Betaglass fabric. This high resin pickup caused the coated Betaglass fabrics to be the stiffest of the materials tested. The thinner, lighter weight Chemglaze coatings ranked next in stiffness. Strike through or penetration of the coating into the fibers was also a contributing factor in the stiffening of Betaglass coated fabrics. However, while all Betaglass coated-fabrics were stiff at room temperature, the coatings could be bent sharply, or folded, at -67°F without cracking. The resin pickup on the remaining three substrates varied dependent upon the liquid

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## PROPERTIES OF FIBROUS SUBSTRATES

	Nylon <u>A-2951/6</u>	Betaglass GV-4030-01	Cerex 5915	Reemay 2011
Weight, oz./sq.yd.	4.5	6.4	1.6	1.2
Thickness, in.	.014	.014	.006	.009
Machine direction	240	197	22	14
<b>Cross direction</b>	203	201	10	8
Fungus Resis⁺ance		NO GROWTH		1
Low Temperature Flexibility		NO CRACKING	5	1
Tear Resistance	NO TEST*	2.Ù	5.9	1.8
Tests after 150 hours accelerated aging				
Breaking Strength, lb:				
Machine direction	195	175	12	8
<b>Cross direction</b>	105	165	01	4
Yisual Examination	NO VISIBLE EFFECT	SL IGHT Darkening	NO VISIBLE	IBLE T →→

\*Individual threads pulled out

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		L-10	0			200	<u>+</u>	
Froperty	Nylon	Beta- glass	Cerex	Reemay	Nylon	Beta- glass	Cerex	Reet
Thickness, in.	.018	.030	.009	.008	.018	.027	.010	.00
Weight, oz./sq. yd.	10.8	19.4	5.6	5.7	10.6	18.4	7.7	6.6
Breaking Strength, 1bs.							<u> </u>	
Machine Direction	251	207	40	15	251	225	46	18
Cross Direction	118	184	23	15	133	211	_ 28	_16
Tear Strength, 1bs. Machine Direction (only)	24	24	10.4	7.6	24	24	4.7	2.8
Fungus Resistance	ج	· · · · · · · · · ·	· · · · · · · · · · · · · · · · · · ·		· · · · · · · · · · · ·			
Low Temperature Flexibility	+	+	· ·····				· · · · ·	-
Heat Sealability	<b>←</b>						SCOLORATION	-
Hydrolytic Stability	<b>«</b>	NO CRACKING	NOT TACK			· –		
Ozone Resistance	<b>~</b>	· · · · ·			NO	CRACKING A	FTER 7 DAYS	
Chemical Resistance	٠						SEE TABLE	VI -
Abrazion Resistance, % Wt. Loss	0.59	-	0.1.7	-	0.62		G.56	-
Tests after 150 hours							4	
accelerated aging: Breaking Strength, 1bs.	150	192	30	14	180	197	34	17
Machine Direction (only)								
Tear Resistance, 1bs.			ļ					
Machine Direction (only)	21	23	5.0	3.0	18	25	5.7	2.
Visual observation	color darkened	surface bubbles	color darkened	color darkened	color darkened	surface bubbles	color darken <b>e</b> d	col dar
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with	,			вб	p2	{		B60	5		
	Cerex	Reemay	Nylon	Beta- glass	Cerex	Reemay	Nylon	Beta- glass	Cerex	Reemay	Ny
	.010	.009	.019	.041	.012	.016	.023	.043	.021	.017	.0
	7.7	6.6	12.8	25.7	7.7	15.3	18.8	24.1	17.4		10.
	46	13	266	190	28	14	266	204			286
	28	16	105	159	22	14	128	174	32	27	161
	4.7	2.8	28	23	6.3	_3.5	26	24	10.4	7.6	26
• •	· · · · · · · · · · ·	NO	UNGAL GROW	th After 28	DAYS				• • • • • • • • • • • • • • • • • •		
			PACKING AT					ی ( ۲۰۰۰ ۲۰۰۰ ۲۰۰۰ ۲۰۰۰ ۲۰۰۰ ۲۰۰۰ ۲۰۰۰ ۲			
	· · · · · · · · · · · · · · · · · · ·	NOT	HEAT SEALA		+ <u></u>		+				<b></b>
DIS	COLORATION		<b>4</b>	NO (	RACKING NOT	TACKY					-
G AF	TER 7 DAYS			<b>.</b>			<b>+</b>	· · · · · · · · · · · · · · · · · · ·			
	SEE TABLE	VI		· · · · ·	1		·····		· · · · · · · · · · · · · · · · · · ·		
	0.56	-	0.30	-	0.15	-	0.11		0.04		0.1
	34	17	281	171	28	9	170	179	_27	12	14
	5.7	2.7	11.2	28	5.6	2.0	12	20	6.2	1.5	19
8	color darkened	color darkened	color darkened	surface bubbles	color darkened	color darkened	color darkened	surface bubbles	color darkened	color darkened	col dar
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TABLE IV PROPERTIES OF UNPIGMENTED COATED-FABRICS

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	ATERIALS	CONTROL M		1	5714F			5	B6D	
	Necprene	Vinyl 1	Reemay	Cerex	Beta- glass	Nylon	Reemay	Cerex_	Pota- glass	ly lon
	.020	.024	.007	.008	.021	.021	.017	.021	.043	.023
	18	23	<u>4.4</u>	4.9	11.1	19.3	11.9	17.4	24.1	8.3
	315	360	16	35	230	286	_30	37	304	. • • •
	285	215	12	20	147	161	27	32	174	128
	30 no growth	29 light growin	3.8	5.5	20	26	7.6	10.4	24	6
	no cracks	oracks	>							
- · ·	ot heat ealable not tacky	sealable a al. tacky	>	-	— HEAT SEA Slight disc	«	>			
<b>3</b>	fail	no cracking pass	····		-					+
	2.9	0.67	-	0.24	-	0.47		0.04	-	.11
	295 _	325	9	25	207	143	12	27	179	70
. <u>-</u>		-								-
	24	26	2	4.7	16	19	1.5	6.2	20	2
	color lightens	color lightens	color darkened	color dårkenèd	pinholes color darkensd	color   darkened -	color darkened	color darkened	surface bubbles	olor Arkened
				,	· · · · · · · · · · · · · · · · · · ·	 				-
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								1	•	*

## 2004 1-100 Beta-Beta-Reemay Nylon glass Cerex Reemay Cerex Froperty Nylon glass .019 .025 .011 .009 .008 .019 .024 .009 laickness, in. 8.6 11.7 18.9 6.8 6.6 10.7 8.1 Weight, oz./sq. yd. 15.1 Breaking Strength, 1bs. 252 197 Machine Direction 213 37 20 35 55 248 Cross Direction 18 176 117 157 21 110 25 14 Tear Scrength, 1bs. Machine Direction (only) 25.5 25 4.8 4.4 2.6 19.3 21.5 7.0 Fungus Resistance **4** Low Temperature Flexibility &----NOT HEAT SEA Heat Sealability 4 . . . . . . . . . A ..... Hydrolytic Stability **6**-----Ozone Resistance ~ ------...... Chemical Resistance 4 Abrasion Resistance, 0.92 \$ Wt. 1088 0.21 0.06 \_ 0.51 -Tests after 150 hrs. accelerated aging: Breaking Strength, 1bs. Machine Direction (only) 15 152 215 32 16 171 195 32 Tear Resistance, 1bs. 15.8 20 5.8 2.6 3.0 19.2 19.3 5.0 Machine Direction (only) surface surface surface Visual observation surface surface surface slight aevere dulls pin holes dulls dulls duils pinholing pinnoling dulls

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		1	· · · · · · · · · · · · · · · · · · ·	вбр	2			B605			
	Cerex	Reemay	Nylon	Beta- glass	Cerex	Reemay	Nylon	Beta- glass	Cerex	Reemay	NyI
	. 709	.008	.021	.030	.011	.012	.018	.031	.012	010	.02
	8.8	6.6	15.9	27.4	14.7	12.3	15.0	22.4	10.7	10.3	9.1
	35	22	232	197	33.	_15	249	.223	38	21	248
	25	14	127	121	22	12	112	167 _	26	20	92
	4.4 . 	2.6	1	19.5 WTH AFTER		3.4	21	23.5	9.8	5.2	25.
	NOT	HEAT SEA		CKING AT -	67°F						<b>4</b>
	· ·		NO CRA	CKING - NO	г таску —						
			- NO CRA	CKING AFTE	r 7 days —	· · · ·					
i.			<b> </b>	SEE TABLE	vi ———						
-	0.92	-	0.12	-	0.08		0.18		0.05		0.7
	32	15	119	202	31	11	119	179	22	12	161
	5.0	2.6	17.2	17.3	6.5	3.5	14.8	20.5	5,6	2,6	19.
Ing	slight pinholing	surface dulls	surface dulls, some pinholing	surface bubbles, pinholing	surface dulls	surface dulls	surface dulls	surface bubbles, some pinholing	surface dulls	dulls	surf dull some pinh
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TABLE V SOFERTIES OF PIGMENTED (BLACK) COATED-FABRICS

(COLUMNAR) (TO BE USED ONLY AS A WORKSHEET .... NOT TO BE OVERPRINTED)

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	<b>B</b> 605				5714	Fl		Control M	aterials	
Nylon	Beta- glass	Cerex	Reemay	Nylon	Beta- glass	Cerex	Reemay	Vinyl	Neoprene	
.019	.031	.012	.010	.020	.023	.008	,008	.024	.020	
15.0	22.4	10.7	10.3	9.1	12.6	6.1	3.4	23	18	
<b>2</b> 49	223	38	21	248	194	24	14	360	315	
112	167	25	20	99	136	16		215	285	
_21	٤،,5	9.8	5.2	25.6	18.7	6 <u>.0</u>	5.0	29 Light growth	3C No	
								Cracks	growth No cracks	
				<b>~</b>	- HEAT SEAL	ABLE		Heat sealable Sl.tacky	Not heat sealable Not tacky	 
					· · · · · · · · · · · · · · · · · · ·		·>	.o cracking Pass	no crackin Fail	6
<b>2.</b> 18	-	0.05	-	0.71		0.67		0.67	2.9	
L19	179	22	12	161	207	26	10	325	295	
<b>.4.</b> 8	20.5	5.6	2.6	19.6	15.3	5.6	2.8	26	24	+
urface Tulls	surface bubbles, some pinholing	Bur <b>îğçe</b> dulls	surface dulls	surface dulls, some pinholing	surface pinholes	surface dulls	surface dulls	color lightens	color 1.gntens	
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polymer used; however, the Estane coatings were generally heavier on the wovens and lighter on the nonwoven fabrics.

The substrate breaking strength was not always increased by application of liquid polymer coatings (Tables IV and V). Almost all of the coated fabrics made with woven substrates had significantly lower cross direction breaking strength. Some loss in strength may be due to variations in the coatings or cures, or due to deterioration by solvents used to dilute the polymers. However, the applied coating increased, significantly, the breaking strength of the coated fabrics made from the nonwoven substrates.

The tear strength of the laboratory-prepared, woven coated-fabrics was similar to that of the commercial controls made by spread or roller systems. Several attempts were made to decrease the penetration of the coating into the fabric and to increase the tearing strength. A base coat (tie-coat) of bis(aminomethyl)cyclohexane in methyl chloride was applied to fabric strips and, while the base coat was still slightly wet, a thin coating of liquid polymer was applied. The coating was dry in approximately one hour, but was very stiff and tear strength was not improved. In a second experiment, a thin coating of a liquid polymer was applied to fabric substrates that were then cured in an atmosphere of sym-dimethyl-ethylenediamine With this treatment, the coatings were so rapidly cured that they became rough and lumpy. Again, tear strength was not improved. In general, the tear strength of the nonwovens was not significantly improved by application of polymer coatings.

All test mater als were fungus- and ozone-resistant, and stiff at -67°F. The vinvl control supported light fungal growth and cracked badly when bent around a onefourth-inch mandrel at -67°F. The neoprene control cracked badly after the day's exposure to ozone.

Only the coated fabrics made from the thermoplastic Estane material were heat sealable. Several attempts were made to coat the thermosetting materials with a thermoplastic resin to obtain heat-sealable materials. The thermoplastic overcoating was only a borderline success. While the coated fabric thus formed was heat sealable, the adhesion between the thermoset and thermoplastic layers was poor. As indicated in Tables IV and V, the vinyl control was heat sealable. Since many coated-fabrics require extended use in an outdoor environment, hydrolytic stability is an important requirement. At this time, no standard procedure is available for testing coated labrics for hydrolytic stability.<sup>5</sup> The poor resistance to hydrolysis of polyester urethanes is well documented.<sup>6</sup>,<sup>7</sup> However, none of the test coatings, including the polyester, became cracked or tacky at the end of the 30-day hydrolysis test (Tables IV and V). Current hydrolytic stability tests for solid ribbers that use a specified loss in stress-strain properties or cracking of stressed specimens as rejection criteria are not adaptable to coated fabrics since the high strength of the coated fabric substrate usually detracts from the value of such testing.

In general, the test coatings were superior in abrasion resistance to the vinyl and neoprene control materials. Both woven and nonwoven base materials were tested for abrasion resistance to determine if the flexibility and smoothness of the substrates would affect the abrasion resistance of the coatings. With the exception of the black pigmented Chemglaze coating, the nonwoven fabric-based coated fabrics had the greater abrasion resistance (Tables IV and V). The latter fabrics are also smoother and more flexible than the woven coated-fabrics.

The insect repellent had a severe effect on the Estane coated-fabrics and on the vinyl control (Table VI). Note that only 2 or 3 drops of the insect repellent were required to cover one-half of each test specimen. Neither the hydrocarbon fuel nor the lubricating oil had any serious effect on the various coated-fabrics.

The breaking-strength loss after accelerated aging was most severe on those coated fabrics containing a woven nylon substrate, i.e., bubbles or pockmarks were evident on some of the coating surfaces. This was true in both the nonpigmented and the pigmented materials. Betaglass based materials were the most resistant to the effects of accelerated aging. Tear strength after accelerated aging varied, possibly, because of further curing by the moisture sensitive materials.

The results obtained on materials aged for six months in Panama are indicated in Table VII. Results indicate that open-sunlight aging had the most severe effect on the laboratory-prepared materials, while the control materials improved somewhat in breaking strength. As shown in the table, three of the laboratory-prepared coated fabrics could

## TABLE VI CHEMICAL RESISTANCE OF UNPIGMENTED AND BL

	Control	Control			1		
	Neoprene/	Viny1/	L-100/	L-100/	<b>ZO</b> 04/	Z004/	:
Chemical	Nylon	Nylon	Nylon	Cerex	Nylon	Cerex	÷
0070126B1					INDIANE	TED COATINGS	┿┙
					UNPIGMEN		$\pm$
IL-L-46000	Very pro-	No	S1. curling	Sl. cwist-	Some yellow	Some yellow	1 5
ubricating 011	nounced curl-	apparent	sl. staining	ing, not	staining,	staining,	
	ing & twisting	effect	+	tacky	not tacky	not tacky	<u>+</u> -
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	1					÷ · · · · · · · · · ·	
		-				-	- - - -
-I-503	Slight curl-	Specimens	S1. curling,	Great deal	S1. curling,		
nsect Repellent	ing, not	curl,	not tacky	of curling,	very tacky	curling, very tacky	· † -
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T-S-735, Type II	No apparent	No	Great deal	Great deal	No	No	÷
ydrocarbon Fuel	effect	apparent	of curling.	of curling,	apparent	apparent	+-
	+	effect	not tecky	not tacky	effect	effect	+
						· · · · · · · · · · · · · · · · · · ·	
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			· · · · · · · · · · · · · · · · · · ·		BLACK PTG	MENTED COATING	13
	See above	See above	No change	No change	No change	Slight	-+-
IIL-L-46000	Dee above	DEC ADOVE				curling	
ubricating Oil					• - • •		ł
			-i		1	+	╉
							ł
		See above	Surface dulls	Slightly	Slight	Severe	1
D-I-503 Insect Repellent	See above	See apove	moderately	vrinkled.	curling.	curling.	
insect nepertent			tacky	slightly	slightly	not tacky	-
				tacky	tacky	+	+
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TT-S-735, Type II	See above	See above	No change	No change	No change	Severe	-+
lydrocarbon Fuel				<u></u>		curling,	$\dashv$
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TARLE VI TANCE OF UNFIGMENTED AND BLACK PIGMENTED COATINGS

TO BE USED ONLY AS A WORKSHEET .... NOT TO BE OVERPRINTED)

J.

TABLE VII COATED FABRICS AGED 6 MOD

Freaking Strength, 1bs., M D only Phickness, inch resence of fungus (Visual) Delamination (Visual) Color change (Visual)**		285 .021 No 2	.021 No		OS 355 025 No	1	<u>.019</u>	019 No	222 .020 Yes	29 022	0S 3.8 .020 No	18.5 022 Yes	<u>.018</u>	.017	Ýев	.014	
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not be tested due to extreme deterioration. All materials except the neoprene control showed evidence of fungus (debris, some viable) when returned from Panama.

In general, coated fabrics made from liquid urethane polymers are equal to or better than the currently available neoprene and vinyl materials, especially with respect to abrasion and ozone resistance, and low-temperature performance. However, liquid urethane polymers are not yet developed at the point in which they can be utilized without solvent dilution or special processing equipment. Thus, an economic disadvantage exists between the currently used neoprene and vinyl coated fabrics, and liquid urethane coated fabrics.

## CONCLUSIONS

1. The viscosity of all liquid polymers with the exception of Chemglaze Z004 had to be reduced to approximately 50 per cent solids to facilitate any type of coating.

2. In almost all instances, the cross-direction breaking strength of the coated substrates was lower than that of the uncoated substrate. This may be due to entrapment of the load-bearing fibers that results in a type of brittleness in the fabric's cross direction.

3. All control and experimental urethane-coated fabrics (including one polyester material) were hydrolytically stable under the test conditions used

4. Generally, the experimental coated-fabrics were superior to the commercial controls in abrasion resistance.

5. The commercial vinyl material and the Estane polyurethane coated-fabric were subject to severe deterioration by 0-I-503 insect repellent.

6. Six months' open-sunlight aging had a more deteriorating effect on laboratory-prepared coated fabrics than the rain-forest aging.

7. The best combination of breaking and tear strength and resistance to accelerated aging was obtained with either a pigmented or nonpigmented liquid polyurethane coated on a Betaglass/Dynel substrate. These experimental materials had abrasion resistance equal to or better than that of the vinyl control and two to three times better than that of the neoprene control. The black pigmented material suffered little or no loss in tear strength after accelerated aging while the control materials lost 10 to 20  $\mu er$  cent in tear strength.

## RECOMMENDATIONS

1. Studies on new liquid polymers, tie-coatings, and substrates should be continued to achieve improvements in future development of fabric coatings in weapon accessories.

2. A hydrolytic stability test should be developed specifically for coated fabrics.

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