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STUDY OF ALIPHATIC DIISOCYANATE CURED POLYURETHANES AND DIISOCYANATE-POLYAMINE POLYUREA COATINGS

BY

STANLEY F. KOUTEK

JUNE 1969

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U. S. ARMY COATING & CHEMICAL LABORATORY
Aberdeen Proving Ground
Maryland

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U. S. ARMY RESEARCH AND DEVELOPMENT CENTER
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ABERDEEN PROVING GROUND, MARYLAND 21005

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ABSTRACT

Two package gloss, semi-gloss and lustreless coatings using an aliphatic diisocyanate cured polyurethane and a polyurea vheicle were formulated into white and olive drab colors. These finishes were evaluated for general performance in corrosion resistance, some chemical, hydraulic fluid and organic solvent resistance and weathering characteristics. The polyurethanes offer good protective and resistance properties and the alphatic diisocyanate cured polyurethanes have the additional advantage of extended gloss and color retention for exterior use as compared to aromatic cured urethanes and polyureas. However, water sensitivity and film brittleness may be a negative factor. The polyurea coatings offer less chemical and solvent resistance than the polyurethanes, but are more flexible and possess good water resistance. Exterior exposure properties are similar to alkyd type enamels.

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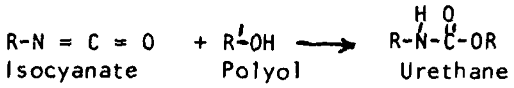
I. INTRODUCTION

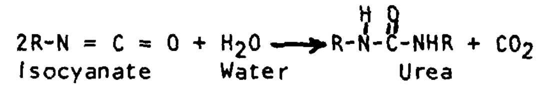
Urethane coatings are gaining increased acceptance for finishes which require chemical, solvent and abrasion resistance. The growth in interior applications may be attributed to these desirable qualities. However, the need for improvement in gloss and color retention for exterior use is recognized, particularly when aromatic diisocyanates are employed. Recently, an aliphatic diisocyanate which should improve weathering properties has been made available. Also, polyurea coatings based on a new polyisocyanate and a polyamine have been introduced. This investigation was thus centered around the isocyanate-adduct, polyol type of two package urethanes and the polyurea type finishes.

Briefly, the basic chemical reaction of urethane coatings is that of an isocyanate with an active hydrogen, usually obtained from a polyhydroxy resin and may be represented as:



$$\underset{\text{Isocyanate}}{R-N=C=O} + \underset{\text{Polyol}}{R'-OH} \longrightarrow \underset{\text{Urethane}}{R-\overset{H}{N}-\overset{O}{\overset{\|}{C}}-OR}$$

Where unreacted isocyanate groups are present, atmospheric moisture is used to complete the cure by the following reaction:



$$\underset{\text{Isocyanate}}{2R-N=C=O} + \underset{\text{Water}}{H_2O} \longrightarrow \underset{\text{Urea}}{R-\overset{H}{N}-\overset{O}{\overset{\|}{C}}-NHR} + CO_2$$

Available hydrogens from amines, fatty acids or those resulting from baking temperatures and side reactions involving the -NCO- group are also present in some systems.

The ASTM recognized conventional urethane coatings are divided into one and two component materials, of which there are five categories:

a. One component systems.

    1. Urethane oils (isocyanate modified drying oils).

    2. Isocyanate terminated adducts or prepolymers (moisture cured).

    3. "Blocked" isocyanate coatings (heat cured).

b. Two component systems.

    1. Isocyanate adduct-polyol coatings.

    2. Prepolymers cured by a catalytic second component (i.e., tertiary amines).

Many isocyanate adduct-polyol coatings contain (1) a component of a prereacted adduct of a polyol and tolylene diisocyanate (TDI) and (2) a component consisting of a polyester, polyether or castor oil. The isocyanate component is furnished as an adduct to reduce the toxicity of tolylene diisocyanate and insure less error in mixing. After the two components are admixed, the polyol cross links with the unreacted isocyanate to form an insoluble, hard film.

Pigmented TDI polyurethane coatings having a very high gloss and sharp reflection of image may be prepared from these resins. These films on exterior exposure chalk rapidly resulting in loss of gloss and color retention and, in addition, white and light tints show considerable yellowing. An aliphatic polyisocyanate adduct, based on hexamethylene diisocyanate (HMDI) in combination with suitable polyester resins was introduced to produce coatings with good weathering properties and still retain the other qualities of TDI polyurethanes.

Another isocyanate reaction is that with an amine to form a urea, as shown:

$$\underset{\text{Isocyanate}}{R\text{-}N = C = O} + \underset{\text{Amine}}{R\ \text{-}NH_2} \longrightarrow \underset{\text{Urea}}{R\text{-}N\text{-}C\text{-}NHR}$$

Recently, polyurea coatings based on this reaction were made available utilizing a dimer diisocyanate and a polyamine. Admixing the two components results in a finish that should be tough, flexible, water, solvent and chemical resistant and have good weathering properties.

All of these materials will cure at temperatures above 40°F. with a relative humidity as low as 35 percent.

II. DETAILS OF TEST

A. Preparation of Coatings

All gloss polyurethanes, polyureas and TT-E-489 Class A alkyd enamels were prepared by charging component I or the grinding mix into a pebble mill and grinding for 48 hours. Semi-gloss coatings (15-25 gloss range) were ground for 24 hours. Lustreless polyurethanes, polyureas and TT-E-527 alkyd enamels were ground for 6 hours in the same manner.

Isocyanate catalyst components were prepared by mixing with the required solvents.

B. Test Panels

Flat-polished 3 by 6 and 4 by 12 inch 1020 cold rolled automotive steel panels were zinc phosphate pretreated with material conforming to to TT-C-490 Type I for use in all tests except flexibility.

Tin panels described in Federal Test Method Standard No. 141, Method 2012, were used for flexibility tests.

C. Application of Coatings

All test panels were primed to a dry film thickness of 0.9 to 1.1 mils with epoxy primer conforming to MIL-P-52192 and air dried for 24 hours at ambient temperatures. The topcoats were applied by spraying to a topcoat dry film thickness of 1.8 to 2.0 mils and allowed to cure a minimum of 7 days at room temperature before initating tests. Reducing solvent for the polyurethanes is given in formula U. Polyureas were reduced with mineral spirits-xylene mixture and the alkyd enamels were thinned as required by their respective specifications.

D. Test Procedures

1. Salt Spray Resistance. Scored panels were exposed to 20 percent salt spray in accordance with Federal Test Method Standard No. 141, Method 6061, for a maximum of 2,000 hours. The specimens were evaluated for score, surface and substrate condition as in Table I.

2. Aerated Water Immersion Resistance. Unscored panels were immersed in aerated distilled water at 95°F. ± 2°F. and examined for blistering and adhesion loss every 24 hours for a maximum of 30 days and rated as in Table II.

3. Resistance to Trichloroethylene Vapors. Unscored panels were suspended for one hour in a vapor phase type degreaser as described in Federal Test Method Standard No. 141, Method 2011, paragraph 4.1.2, allowed to cool and examined for film softening, adhesion loss or removal.

4. Impact Resistance. Direct and reverse impact tests were conducted on primed panels by dropping a one pound steel ball onto the panel surface from a height of 5 feet. Film cracking and/or flaking was noted.

5. Flexibility. Tin panels, one set topcoated only and another set with MIL-P-52192 epoxy primer - topcoat system, were bent over 1/8 and 1/4 inch mandrels and examined under 5 power magnification for cracks or other defects along the bend area.

6. Humidity Cycle. Unscored panels were exposed to a humidity cycle comparable to MIL. Standard 202C, Method 106B, without the -10°C. portion. A humidity cabinet equipped with a saturable reactor, cam type programmer and controller complete with recorder was used for the following cycle: Start 25°C., R.H. ambient, 2-1/2 hours to 65°C., 92-98% R.H.; hold 65°C., 92-98% R.H. for 3 hours; return to 25°C., 92-98% R.H. in 2-1/2 hours; hold 25°C., 92-98% R.H. for 7-1/2 hours; return to 65°C., 92-98% R.H. in 2-1/2 hours; hold 65°C., 92-98% R.H. for 3-1/2 hours; return to 25°C., 92-98% R.H. in 2-1/2 hours; one cycle - 24 hours.

After 10 complete cycles, the panels were removed and inspected for blistering and adhesion.

7. Immersion Tests.

(a) Diester Fluid - 250°F. Unscored panels were immersed for 24 hours in 250°F. diester fluid conforming to specification MIL-H-19457B, removed, allowed to cool and examined for blistering, adhesion and discoloration.

(b) Hydraulic Fluid Immersions. Unscored panels were immersed in fluids conforming to specifications MIL-H-5606B, MIL-H-19457B and MIL-H-22072 at ambient temperatures. The panels were examined periodically for blistering, adhesion and discoloration for a maximum of 30 days.

(c) Sodium Hydroxide 5 Percent. Unscored panels were immersed at ambient temperatures in a 5 percent by weight solution of sodium hydroxide, which was titrated periodically to maintain the proper concentration. Test specimens were examined every 24 hours and rated after a maximum of 30 days.

(d) Hydrochloric Acid 5 Percent. Test panels were immersed in a 5 percent by weight solution of hydrochloric acid and treated as in c above.

(e) Methyl Isobutyl Ketone Resistance. Unscored panels were immersed in methyl isobutyl ketone at ambient temperatures and rated after 30 days.

8. Gloss Determinations. Gloss checks were made for the HMDI urethanes and polyurea enamels by drawing down a 0.003 mil wet film of the admixed coatings on glass 30 minutes after mixing and at 1 hour intervals thereafter for 7 hours. Gloss measurements were taken after 24 hours cure at ambient temperatures.

9. Weatherometer Exposure. Unscored panels were placed in a twin arc weatherometer in accordance with Federal Test Method Standard No. 141, Method 6152, and evaluated for chalking, specular gloss and color change at 168, 500, 1000 and 2000 hours.

10. Exterior Exposure. Unscored panels were exposed at the Panama Open Field Site and at Aberdeen Proving Ground, Maryland for weathering studies. Evaluations were made at approximately 6 months, 1 year and 2 years.

III. DISCUSSION

Gloss, semi-gloss and lustreless white and olive drab coatings were formulated and prepared using the aliphatic diisocyanate system (HMDI) and the polyurea vehicles. Aromatic diisocyanate polyurethane (TDI) gloss white and olive drab were included for control purposes. White and olive drab enamels conforming to TT-E-489 Class A were used to compare flexibility, impact resistance, gloss and color change for gloss coatings, TT-E-529 Class A for semi-gloss and TT-E-527 for lustreless.

Formula A conforms to specification MIL-C-27227, white gloss, tolylene diisocyanate polyurethane and Formula B, olive drab gloss, was developed using the same resin system. Polyurethane white and olive drab gloss coatings employing an aliphatic diisocyanate (HMDI) are given in Formulas C and D. White and olive drab gloss polyureas are shown in Formulas E and F and the TT-E-489 Class A controls are represented by Formulas G and H. Semi-gloss white and olive drab formulations for polyurethane, polyurea and TT-E-529 Class A coatings are given in Formulas I, J, K, L, M and N respectively. Comparable lustreless formulas are O, P, Q, R, S and T.

Salt Spray (Table III). Medium to heavy score rusting was evident on all test panels after 2000 hours salt spray exposure. Blistering was observed along the score on the polyurea and alkyd control topcoats. There were no further surface or substrate defects.

Aerated Water Immersion (Table IV). The HMDI polyurethane gloss enamels (Formulas C and D) had medium dense blisters after 144 hours and were more sensitive to water immersion than gloss TDI enamels. Semi-gloss topcoats (Formulas I and J) had medium blisters after 30 days and the lustreless (Formulas O and P) had few blisters. Polyurea gloss, semi-gloss and lustreless coatings (Formulas E, F, K, L, Q and R) were without defects after 30 days immersion. All alkyd controls blistered within 24 hours. The polyurea systems offered the best water immersion resistance.

Resistance to Trichloroethylene Vapors (Table V). After 1 hour exposure, all topcoats, except the white semi-gloss and lustreless polyurea coatings, exhibited either blistering, softening, wrinkling, poor intercoat adhesion or combinations thereof. Alkyd controls were not exposed to the vapors since their resistance is known to be unsatisfactory. It is recognized that one hour exposure to trichloroethylene vapors is a severe test and under normal degreasing cycles, these coatings may perform adequately.

Impact Resistance (Table VI). All topcoats were without defects upon direct impact. On reverse impact, all polyurethane topcoats except Formula D had flaking and/or cracking. Polyureas and the alkyd controls were without defects.

Flexibility (Table VII). TDI gloss polyurethanes (Formulas A and B) had lifting or cracking on 1/8 and 1/4 inch bends with primed and unprimed surfaces. HMDI gloss polyurethanes (Formulas C and D) exhibited no defects on 1/4 inch bend but some fine cracking was present on primed tin over a 1/8 inch mandrel. Semi-gloss and lustreless (Formulas I, J, O and P) cracked and/or lifted with and without the primer. Polyurea gloss and semi-gloss coatings (Formulas E, F, K and L) had no defects. The lustreless polyureas (Q and R) had fine cracks over primed tin bent over the 1/8 inch mandrel. Alkyd controls were satisfactory.

Humidity Cycle (Table VIII). All coatings were without defects after 10 cycles.

Immersion Tests

(a) Diester Fluid 250°F. (Table IX). Polyurethane gloss, semi-gloss and lustreless coatings had no defects except a slight yellowing of white TDI gloss, Formula A. Polyurea finishes became soft and were easily removed from the primer. Whites yellowed considerably and blistering was evident on all olive drab polyureas. Alkyd finishes were not tested.

(b) Hydraulic Fluid Immersions (Table X). All polyurethane coatings had good resistance to the fluids, being unchanged after 30 days. All white polyureas showed a slight softening and pink discoloration in MIL-H-5606B; the olive drabs softened slightly. In MIL-H-19457B, polyurea whites yellowed and olive drab softened, and in MIL-H-22072 the polyureas softened moderately. These polyureas would not be recommended for continuous hydraulic fluid exposure, however, spillage or intermittent contact should not prove detrimental.

(c) Sodium Hydroxide 5 Percent (Table XI). Polyurethane gloss, semi-gloss and polyurea gloss enamels (Formulas A, B, C, D, E, F, I and J) were without defects after 30 days immersion. The polyurea white semi-gloss (Formula K) blistered and softened; the olive drab was satisfactory. All lustreless topcoats blistered and, in addition, the polyureas softened considerably. Mild alkali resistance decreased as pigmentation increased.

(d) Hydrochloric Acid 5 Percent (Table XII). Polyurethane and polyurea gloss enamels were without blisters or softening after 30 days immersion. However, the polyureas (Formulas E and F) developed a surface haze which resulted in a considerable loss of gloss. Semi-gloss topcoats were without defects. All lustreless coatings blistered with considerable softening of the polyurea films.

(e) Methyl Isobutyl Ketone (Table XIII). TDI gloss (Formulas A and B) and all polyurea coatings (Formulas E, F, K, L, Q and R) softened considerably after 30 days immersion. All HMDI coatings (Formulas C, D, I, J, O and P) were satisfactory.

Gloss Determinations (Table XIV). HMDI gloss topcoats (Formulas C and D) maintained 60° gloss 7 hours after admixing, having no loss in white and 5 gloss units loss in olive drab. Twenty degree gloss was satisfactory in white, losing 3 units; olive drab ranged from 90 to 64 in 7 hours producing a definite haze. Polyurea gloss enamels (Formulas E and F) had lower initial 60° gloss than the polyurethanes and although reduction with xylene improved the gloss, hazing was apparent.

Polyurethane white semi-gloss (Formula I) had a 60° gloss range of 68 to 48, too high in gloss although formulated at a semi-gloss pigment volume concentration. The olive drab (Formula J) was initally satisfactory having a 60° gloss of 21, but as the reaction progressed, the gloss declined to 8.5 after 7 hours. The polyurea semi-gloss white and olive drab (Formulas K and L) were within a reasonable gloss range for the 7 hour period, particularly from 1 hour after admixing. Lustreless coatings (Formulas O, P, Q and R) were satisfactory and appear practical for this application.

Weatherometer Exposure (Table XV). TDI gloss polyurethanes (Formulas A and B) showed a considerable loss of 60° gloss after 500 hours, 71 and 84 units respectively and almost a complete loss of 20° gloss. There was a significant color change in olive drab. HMID polyurethanes (Formulas C and D) showed appreciably less loss, decreasing 26 and 10 60° gloss units after 500 hours and 61 and 46 units after 2000 hours. Color change for olive drab was relatively insignificant. The polyurea enamels (Formulas E and F) had better gloss and color retention than TDI coatings A and B, but were inferior to the HMDI coatings C and D. Alkyd controls (Formulas G and H) and the polyureas were comparable in gloss and color retention. Semi-gloss coatings performed in a similar pattern.

In the lustreless series, HMDI topcoats (Formulas O and P) had the best color retention but 85° sheen increased more than the TT-E-527 enamels. The polyurea white lustreless likewise increased in sheen.

Exterior Exposure

(a) Panama Open Field Site (Table XVI, Figures 1 and 2). The TDI white gloss (Formula A) was almost lustreless and chalked excessively after 7 months exposure, losing 90.5, 60° gloss units and 100.0, 20° gloss units. HMDI white gloss (Formula C) retained most of the original gloss after 7 months. The 60° gloss lost 10 units and 20°, 17 units. Polyurea gloss white (Formula E) and TT-E-489 control (Formula G) were similar in gloss retention, losing 46 and 39 units respectively. Figure 1 illustrates the comparison of gloss white coatings to 22 months exposure. The curves show the HMDI polyurethane coating maintained appreciably higher gloss after 13 months exposure but declined between 13 and 22 months to the level of the polyurea and alkyd whites. Exposure results for the olive drab gloss coatings (Formulas B, D, F and H) were comparable to the white (Figure 2).

Semi-gloss HMDI polyurethanes (Formulas I and J) likewise chalked less and retained the most 60° gloss after 13 months exposure This advantage also narrowed after 22 months.

All lustreless coatings had comparable 60° gloss and color retention properties. However, an undesired increase in 85° sheen was more apparent in the HMDI white and olive drab (Formulas O and P) than in the other coatings.

(b) Aberdeen Proving Ground, Maryland (Table XVII, Figures 3 and 4). Under conditions where ultraviolet light was not as severe as in Panama, the HMDI gloss polyurethanes (Formulas C and D) were superior to the polyureas (Formulas E and F) and TT-E-489 controls (Formulas G and H) in retention of gloss, color and sharpness of image. Figure 3 shows HMDI white (Formula C) lost 9 gloss units after 13 months exposure compared to 58.5 units for the polyurea white (E) and 37 units for the alkyd white (G). After 25 months, the HMDI white retained more gloss than the other whites but not as significantly. Olive drab gloss enamels (Formulas B, D, F and H) performed comparably (Figure 4). Semi-gloss coatings weathered in the same manner as the gloss finishes. HMDI lustreless topcoats (Formulas O and P) again increased in sheen.

IV. CONCLUSIONS

The advantage of the aliphatic diisocyanate cured polyurethane enamels is the improved exterior exposure gloss and color retentive properties without undue sacrifice to other polyurethane performance characteristics. Tolylene diisocyanate cured polyurethane coatings exhibit excessive chalking, loss of gloss and poor color retention within short periods of time when used outdoors. The HMDI polyurethanes are definitely superior in this respect. Except for lustreless coatings these polyurethane finishes will perform satisfactorily in corrosive atmospheres, hydraulic fluids, mild chemical solutions and in most organic solvents and be applicable for exterior use where gloss and color are of significant value. It is apparent that sensivity to water is a factor to be considered in using polyurethanes since prolonged water contact produced varying degrees of topcoat blistering. Careful selection of substrate pretreatment and primer are of critical importance as other studies in progress indicate that primers containing slightly soluble chromate pigments enhance the possibility of polyurethane topcoat blistering under water contact. For use in areas subjected to flex-stressing and conditions relating to impact, the polyurethanes, as formulated in this evaluation, are brittle, resulting in film cracking or flaking. The elasticity of polyurethanes can be varied by the polyol resins used and further development may result in more elastomeric films which possess the other desired qualities.

Semi-gloss polyurethanes appeared impractical for lack of gloss control. Lustreless coatings may be developed if sheen increase on exterior exposure is corrected or not critical.

The polyurea coatings tested were quite satisfactory when exposed to water for prolonged periods and had flexibility comparable to the alkyd controls. They have limited chemical, hydraulic fluid and organic solvent resistance, somewhat better than the alkyd finishes but inferior to the polyurethanes. Weathering properties were similar to the alkyd control enamels. Semi-gloss and lustreless finishes could be satisfactorily developed using these vehicles.

APPENDIX A

Formula A

MIL-C-27227 Coating, Polyurethane, Thermal Resistant For Aircraft Application, White Gloss

Ingredient	Pounds	Gallons
Component I, Pigmented Polyester Resin		
Rutile titanium dioxide	445.0	12.7
Stearated aluminum silicate	62.5	2.8
Polyester resin, 280-300 hydroxyl No.	97.2	10.2
Polyester resin, 215-235 hydroxyl No.	97.2	10.2
Polyester resin, 140-160 hydroxyl No.	195.0	20.5
Ethyl acetate (urethane grade)	184.5	24.4
Cellosolve acetate (urethane grade)	100.0	12.3
Toluene	45.5	6.3
Cellulose acetate butyrate 1/2 sec.	3.0	0.3
Ultra-violet light stabilizer	3.5	0.3
	1233.4	100.0
Component II, Tolylene Diisocyanate Catalyst		
Cellosolve acetate (urethane grade)	121.7	15.0
Isocyanate resin, 60% N.V.	650.0	70.0
Xylene	108.0	15.0
	879.7	100.0

Mix 1 part component I with 1 part component II by volume.

Total solids = 61.2%
Pigment = 24.2%
Vehicle solids = 37.0%
Pigment volume concentration = 17.1%

Formula B

Polyurethane Olive Drab Gloss, Tolylene Diisocyanate Cure

Ingredient	Pounds	Gallons
Component I, Pigmented Polyester Resin		
Yellow iron oxide, 87% Fe_2O_3	111.6	3.3
Medium lead chromate	58.8	1.3
Carbon black	26.2	1.8
Red iron oixde, 98% Fe_2O_3	30.0	0.7
Rutile Titanium dioxide	17.5	0.5
Anti-float agent	2.4	0.1
Stearated aluminum silicate	27.9	1.3
Polyester resin, 280-300 hydroxyl No.	111.9	11.9
Polyester resin, 215-235 hydroxyl No.	111.9	11.9
Polyester resin 140-160 hydroxyl No.	225.6	24.0
Ethyl acetate (urethane grade)	184.7	24.6
Cellosolve acetate (urethane grade)	94.0	11.6
Toluene	44.8	6.2
Cellulose acetate butyrate 1/2 sec.	4.0	0.4
Ultra-violet light stabilizer	4.7	0.4
	1056.0	100.0
Component II, Tolylene Diisocyanate Catalyst		
Cellosolve acetate (urethane grade)	81.8	10.1
Isocyanate resin, 60% N.V.	750.2	79.8
Xylene	72.9	10.1
	904.9	100.0

Mix 1 part component I with 1 part component II by volume.

Total solids = 60.3%
Pigment = 14.1%
Vehicle solids = 46.2%
Pigment volume concentration = 9.5%

Formula C

Polyurethane White Gloss, Hexamethylene Diisocyanate Cure

Ingredient	Pounds	Gallons
Component I, Pigmented Polyester Resin		
Rutile titanium dioxide	277.5	7.9
Polyester resin, 260-280 hydroxyl No.	237.3	21.7
Silicone resin, 60% N.V.	0.3	--
Ethyl acetate (urethane grade)	111.0	14.8
Methyl ethyl ketone	36.9	5.5
Cellosolve acetate (urethane grade)	37.0	4.6
Toluene	37.0	5.1
8% zinc octoate, 35% N.V.	0.5	0.1
Cellulose acetate butyrate 1/2 sec.	2.9	0.3
	740.4	60.0
Component II, Hexamethylene Diisocyanate Catalyst		
Cellosolve acetate (urethane grade)	27.9	3.4
Isocyanate resin, 75% N.V.	289.4	32.4
Methyl ethyl ketone	27.8	4.2
	345.1	40.0

Mix 3 parts component I with 2 parts component II by volume.

Total solids = 67.7%
Pigment = 25.6%
Vehicle solids = 42.1%
Pigment volume concentration = 15.0%

Formula D

Polyurethane Olive Drab Gloss, Hexamethylene Diisocyanate Cure

Ingredient	Pounds	Gallons
Component I, Pigmented Polyester Resin		
Yellow iron oxide, 87% Fe_2O_3	56.1	1.7
Medium lead chromate	28.5	0.6
Carbon black	13.4	0.9
Red iron oxide, 98% Fe_2O_3	15.9	0.4
Rutile titanium dioxide	8.0	0.2
Polyester resin, 260-280 hydroxyl No.	230.6	21.1
Silicone resin, 60% N.V.	0.3	--
Ethyl acetate (urethane grade)	128.6	17.1
Methyl ethyl ketone	42.7	6.4
Cellosolve acetate (urethane grade)	42.8	5.3
Xylene	42.7	5.9
8% zinc octoate, 35% N.V.	0.6	0.1
Cellulose acetate butyrate 1/2 sec.	2.8	0.3
	613.0	60.0
Component II, Hexamethylene Diisocyanate Catalyst		
Cellosolve acetate (urethane grade)	31.3	3.9
Isocyanate resin, 75% N.V.	281.2	31.5
Methyl ethyl ketone	31.2	4.6
	343.7	40.0

Mix 3 parts component I with 2 parts component II by volume.

Total solids = 59.2%
Pigment = 12.7%
Vehicle solids = 46.5%
Pigment volume concentration = 8.0%

Polyurea White and Olive Drab Gloss

Ingredient	Formula E White Pounds	Formula E White Gallons	Formula F Olive Drab Pounds	Formula F Olive Drab Gallons
Component I, Pigmented Modified Amine				
Rutile titanium dioxide	502.4	14.4	17.4	0.4
Yellow iron oxide, 87% Fe_2O_3	--	--	121.8	3.6
Medium lead chromate	--	--	61.6	1.4
Carbon black	--	--	23.0	1.6
Red iron oxide, 98% Fe_2O_3	--	--	33.4	0.8
Modified amine, 45% N.V.	579.8	80.0	640.0	88.4
Xylene	40.2	5.6	27.4	3.8
	1122.4	100.0	924.6	100.0
Component II, Diisocyanate Solution				
Diisocyanate resin, 65% N.V.	597.4	82.4	659.2	91.0
Xylene	127.0	17.6	65.6	9.0
	724.4	100.0	724.8	100.0

Mix 1 part component I with 1 part component II by volume.

	Formula E	Formula F
Total solids	62.4%	59.0%
Pigment	27.2%	15.6%
Vehicle solids	35.2%	43.4%
Pigment volume concentration	15.0%	8.0%

TT-E-489 Class A, White and Olive Drab Gloss Enamels

Ingredient	Formula G White Pounds	 Gallons	Formula H Olive Drab Pounds	 Gallons
Rutile titanium dioxide	234.1	6.7	7.0	0.2
Yellow iron oxide, 87% Fe_2O_3	--	--	44.0	1.3
Medium lead chromate	--	--	27.1	0.6
Carbon black	--	--	8.7	0.6
Red iron oxide, 98% Fe_2O_3	--	--	8.6	0.2
TT-R-266 Type II alkyd	603.0	78.4	625.4	81.3
Mineral spirits	87.9	13.4	95.1	14.5
24% lead napthenate	5.8	0.6	5.9	0.6
5% calcium napthenate	2.0	0.2	2.1	0.3
6% cobalt napthenate	3.8	0.5	2.0	0.2
Anti-skinning agent	1.5	0.2	1.5	0.2
	938.1	100.0	827.4	100.0

	Formula G	Formula H
Total solids	58.0%	50.2%
Pigment	25.5%	12.0%
Vehicle solids	32.5%	38.2%
Pigment volume concentration	17.0%	8.0%

Formula I

Polyurethane White Semi-Gloss, Hexamethylene Diisocyanate Cure

Ingredient	Pounds	Gallons
Component I, Pigmented Polyester Resin		
Rutile titanium dioxide	381.4	10.9
Fibrous magnesium silicate	299.8	12.8
Suspension agent	7.5	0.5
Polyester resin, 260-280 hydroxyl No.	273.3	25.0
Silicone resin, 60% N.V.	0.7	0.1
Ethyl acetate (urethane grade)	187.0	24.9
Methyl ethyl ketone	62.3	9.3
Cellosolve acetate (urethane grade)	62.4	7.7
Toluene	62.8	8.7
8% zinc octoate, 35% N.V.	0.7	0.1
	1337.9	100.0
Component II, Hexamethylene Diisocyanate Catalyst		
Cellosolve acetate (urethane grade)	46.2	5.7
Isocyanate resin, 75% N.V.	333.9	37.4
Methyl ethyl ketone	46.2	6.9
	426.3	50.0

Mix 2 parts component I with 1 part component II by volume.

Total solids = 68.7%
Pigment = 39.0%
Vehicle solids = 29.7%
Pigment volume concentration = 31.9%

Formula J

Polyurethane Olive Drab Semi-Gloss, Hexamethylene Diisocyanate Cure

Ingredient	Pounds	Gallons
Component I, Pigmented Polyester Resin		
Yellow iron oxide, 87% Fe_2O_3	142.0	4.2
Medium lead chromate	31.6	0.7
Carbon black	11.7	0.8
Red iron oxide	17.2	0.4
Rutile titanium dioxide	3.5	0.1
Fibrous magnesium silicate	138.9	6.0
Barytes	63.1	1.7
Suspension agent	6.0	0.4
Polyester resin, 260-280 hydroxyl No.	254.7	23.3
Silicone resin, 60% N.V.	0.7	0.1
Ethyl acetate (urethane grade)	232.1	30.9
Methyl ethyl ketone	74.4	11.1
Cellosolve acetate (urethane grade)	91.5	11.3
Xylene	64.3	8.9
8% zinc octoate, 35% N.V.	0.7	0.1
	1132.4	100.0
Component II, Hexamethylene Diisocyanate Catalyst		
Cellosolve acetate (urethane grade)	55.9	6.9
Isocyanate resin, 75% N.V.	309.9	34.7
Methyl ethyl ketone	56.3	8.4
	422.1	50.0

Mix 2 parts component I with 1 part component II by volume.

Total solids = 58.2%
Pigment = 26.7%
Vehicle solids = 31.5%
Pigment volume concentration = 23.0%

Polyurea White and Olive Drab Semi-Gloss

	Formula K		Formula L	
	White		Olive Drab	
Ingredient	Pounds	Gallons	Pounds	Gallons
Component I, Pigmented Modified Amine				
Rutile titanium dioxide	324.0	9.3	4.2	0.1
Yellow iron oxide, 87% Fe_2O_3	--	--	168.4	5.0
Medium lead chromate	--	--	36.2	0.8
Carbon black	--	--	14.6	1.0
Red iron oxide, 98% Fe_2O_3	--	--	19.8	0.5
Suspension agent	6.6	0.4	6.6	0.4
Anti-float agent	--	--	4.8	0.2
Fibrous magnesium silicate	254.6	10.9	157.8	6.8
Barytes	--	--	72.0	1.9
Modified amine, 45% N.V.	323.8	44.7	421.2	58.2
Toluene	250.8	34.7	181.0	25.1
	1159.8	100.0	1086.6	100.0
Component II, Diisocyanate Solution				
Diisocyanate resin, 65% N.V.	333.4	46.0	434.0	59.9
Toluene	389.8	54.0	289.8	40.1
	723.2	100.0	723.8	100.0

Mix 1 part component I with 1 part component II by volume.

Total solids	50.3%	52.8%
Pigment	31.1%	26.7%
Vehicle solids	19.2%	26.1%
Pigment volume concentration	31.0%	22.0%

TT-E-529 Class A, White and Olive Drab Semi-Gloss

Ingredient	Formula M White Pounds	Formula M White Gallons	Formula N Olive Drab Pounds	Formula N Olive Drab Gallons
Rutile titanium dioxide	224.3	6.4	2.5	0.1
Yellow iron oxide, 87% Fe_2O_3	--	--	95.7	2.8
Medium lead chromate	--	--	21.2	0.5
Carbon black	--	--	8.0	0.6
Red iron oxide	--	--	10.7	0.2
Fibrous magnesium silicate	125.6	5.4	122.4	5.2
Barytes	55.3	1.5	41.0	1.1
TT-R-266 Type III alkyd	481.5	62.6	510.6	66.4
Mineral spirits	151.6	23.1	144.4	22.0
24% lead napthenate	4.0	0.4	5.2	0.5
5% calcium napthenate	1.5	0.2	1.7	0.2
6% cobalt napthenate	1.5	0.2	1.8	0.2
Anti-skinning agent	1.3	0.2	1.2	0.2
	1046.6	100.0	966.4	100.0

	Formula M	Formula N
Total solids	62.2%	58.2%
Pigment	39.0%	31.2%
Vehicle solids	23.2%	27.0%
Pigment volume concentration	33.6%	27.3%

Formula O

Polyurethane White Lustreless, Hexamethylene Diisocyanate Cure

Ingredient	Pounds	Gallons
Component I, Pigmented Polyester Resin		
Rutile titanium dioxide	280.0	8.0
Fibrous magnesium silicate	187.5	7.9
Micronized magnesium silicate	79.0	3.5
Suspension agent	6.0	0.4
Polyester resin, 260-280 hydroxyl No.	138.8	12.7
Ethyl acetate (urethane grade)	249.3	33.2
Methyl ethyl ketone	83.1	12.4
Cellosolve acetate (urethane grade)	83.4	10.3
Toluene	83.0	11.5
8% zinc octoate, 35% N.V.	0.7	0.1
	1190.8	100.0
Component II, Hexamethylene Diisocyanate Catalyst		
Cellosolve acetate (urethane grade)	113.4	14.0
Isocyanate resin, 75% N.V.	169.7	19.0
Methyl ethyl ketone	113.9	17.0
	397.0	50.0

Mix 2 parts component I with 1 part component II by volume.

Total solids = 51.5%
Pigment = 34.7%
Vehicle solids = 16.8%
Pigment volume concentration = 43.0%

Formula P

Polyurethane Olive Drab Lustreless, Hexamethylene Diisocyanate Cure

Ingredient	Pounds	Gallons
Component I, Pigmented Polyester Resin		
Yellow iron oxide, 87% Fe_2O_3	177.9	5.3
Carbon black	8.7	0.6
Red iron oxide, 98% Fe_2O_3	0.7	--
Fibrous magnesium silicate	303.9	12.8
Suspension agent	4.5	0.3
Polyester resin, 260-280 hydroxyl No.	145.4	13.3
Ethyl acetate (urethane grade)	250.1	33.3
Methyl ethyl ketone	83.1	12.4
Cellosolve acetate (urethane grade)	83.4	10.3
Toluene	83.7	11.6
8% zinc octoate, 35% N.V.	0.7	0.1
	1142.1	100.0
Component II, Hexamethylene Diisocyanate Catalyst		
Cellosolve acetate (urethane grade)	111.0	13.7
Isocyanate resin, 75% N.V.	175.9	19.7
Methyl ethyl ketone	111.2	16.6
	398.1	50.0

Mix 2 parts component I with 1 part component II by volume.

Total solids = 50.0%
Pigment = 32.0%
Vehicle solids = 18.0%
Pigment volume concentration = 41.0%

Polyurea White and Olive Drab Lustreless

	Formula Q		Formula R	
	White		Olive Drab	
Ingredient	Pounds	Gallons	Pounds	Gallons
Component I, Pigmented Modified Amine				
Rutile titanium dioxide	310.0	9.0	--	--
Yellow iron oxide, 87% Fe_2O_3	--	--	214.8	6.4
Carbon black	--	--	11.7	0.8
Red iron oxide, 98% Fe_2O_3	--	--	0.7	--
Fibrous magnesium silicate	208.9	8.8	375.1	15.8
Micronized magnesium silicate	88.0	3.9	--	--
Suspension agent	6.0	0.4	4.5	0.3
Modified amine, 45% N.V.	207.7	28.7	236.7	32.7
Mineral spirits	321.8	49.2	287.8	44.0
	1142.4	100.0	1131.3	100.0
Component II, Diisocyanate Solution				
Diisocyanate resin, 65% N.V.	213.9	29.5	244.3	33.7
Mineral spirits	134.1	20.5	106.6	16.3
	348.0	50.0	350.9	50.0

Mix 2 parts component I with 1 part component II by volume.

Total solids	56.9%	58.8%
Pigment	41.3%	40.9%
Vehicle solids	15.6%	17.9%
Pigment volume concentration	43.0%	41.0%

TT-E-527, White and Olive Drab Lustreless

Ingredient	Formula S White Pounds	Formula S White Gallons	Formula T Olive Drab Pounds	Formula T Olive Drab Gallons
Rutile titanium dioxide	246.7	7.1	--	--
Yellow iron oxide, 87% Fe_2O_3	--	--	154.8	4.6
Carbon black	--	--	8.3	0.6
Red iron oxide, 98% Fe_2O_3	--	--	0.5	--
Suspension agent	4.5	0.3	3.2	0.2
Fibrous magnesium silicate	166.5	6.9	270.9	11.4
Micronized magensium silicate	71.4	3.1	--	--
TT-R-266 Type III alkyd	423.8	55.1	437.5	56.9
Mineral spirits	173.9	26.5	166.7	25.4
24% lead napthenate	4.6	0.5	3.8	0.4
5% calcium napthenate	1.4	0.2	1.4	0.2
6% cobalt napthenate	1.5	0.2	1.4	0.2
Anti-skinning agent	1.0	0.1	1.1	0.1
	1095.3	100.0	1049.6	100.0

	Formula S	Formula T
Total solids	64.4%	63.0%
Pigment	44.7%	41.8%
Vehicle solids	19.7%	21.2%
Pigment volume concentration	42.9%	41.3%

Formula U

Reducing Solvent for Polyurethane Coatings

Ingredient	Parts by Volume
Ethyl acetate (urethane grade)	55
Cellosolve acetate (urethane grade)	30
Toluene	15
	100

APPENDIX B

TABLE I

Rating System for Salt Spray Exposure

Numerical Rating	Score (Blistering, Rusting and/or Undercutting to Either Side of Score)	Surface, Other Than Score (Blistering, Rusting)	Substrate Other Than Score (Rusting Pitting)
5	None to 1/32 inch	None	None
4	1/32 to 1/16 inch	ASTM, Photo 10 Type I[1]	Trace, less than 5 spots, ASTM Size #8[2]
3	1/16 to 1/8 inch	ASTM, Photo 8 Type II	ASTM, few
2	1/8 to 3/16 inch	ASTM, Photo 7 Type II	ASTM, medium
1	3/16 to 1/4 inch	ASTM, Photo 6 Type II	ASTM, medium-dense
0	1/4 inch and above	ASTM, Photo 4 Type II	ASTM, dense

[1] Reference Standards; Federal Test Method Standard No. 141a, Method 6451.
[2] Reference Standards; Federal Test Method Standard No. 141a, Method 6461.

TABLE II

Rating System for Aerated Water Immersion

Numerical Rating	Surface Blisters[2]
5	None
4	ASTM few, blister size No. 8 or smaller
3	Astm few, blister size No. 6 to 4
2	ASTM medium, blister size No. 8 to 6
1	ASTM medium dense, blister size No. 8 to 4
0	ASTM dense, blister size No. 8 to 2

[2] Reference Standards; Federal Test Method Standard No. 141a, Method 6461.

TABLE III

Salt Spray Exposure

Topcoat Formula	Hours Exposed	Rating Upon Removal		
		Score	Surface	Substrate
A	2000	2	5	5
B	2000	2	5	5
C	2000	3	5	5
D	2000	3	5	5
E	2000	3	5	5
F	2000	3	5	5
G	2000	3	5	5
H	2000	3	5	5
I	2000	3	5	5
J	2000	2	5	5
K	2000	3	5	5
L	2000	3	5	5
M	2000	3	5	5
N	2000	3	5	5
O	2000	3	5	5
P	2000	3	5	5
Q	2000	3	5	5
R	2000	3	5	5
S	2000	2	5	5
T	2000	2	5	5

TABLE IV

Aerated Water Immersion

Topcoat Formula	Time Immersed	Rating Upon Removal
A	30 days	4
B	30 days	4
C	144 hrs	2
D	144 hrs	2
E	30 days	5
F	30 days	5
G	24 hrs	2
H	24 hrs	2
I	30 days	2
J	30 days	2
K	30 days	5
L	30 days	5
M	24 hrs	2
N	24 hrs	2
O	30 days	4
P	30 days	4
Q	30 days	5
R	30 days	5
S	24 hrs	2
T	24 hrs	2

TABLE V

Resistance to Trichloroethylene Vapors

Topcoat Formula	Condition Upon Removal
A	Dense blisters size ASTM #8, moderate softening
B	Dense blisters size ASTM #8, moderate softening
C	Dense blisters size ASTM #8, considerable softening
D	Dense blisters size ASTM #8, considerable softening
E	Film wrinkled; considerable softening, poor primer adhesion
F	Film wrinkled; considerable softening, poor primer adhesion
I	Moderate softening, no other defects
J	Medium blisters size ASTM #8, considerable softening
K	No defects
L	Considerable softening, poor intercoat adhesion
O	Medium blisters size ASTM #8, moderate softening
P	Considerable softening, no other defects
Q	No defects
R	Film wrinkled and lifted from primer

TABLE VI

Impact Resistance

Topcoat Formula	Direct	Reverse
A	No defects	System flaked off substrate
B	No defects	System flaked off substrate
C	No defects	System cracked and flaked off substrate
D	No defects	No defects
E	No defects	No defects
F	No defects	No defects
G	No defects	No defects
H	No defects	No defects
I	No defects	Fine cracks
J	No defects	Fine cracks
K	No defects	No defects
L	No defects	No defects
M	No defects	No defects
N	No defects	No defects
O	No defects	Fine cracks
P	No defects	Fine cracks
Q	No defects	No defects
R	No defects	No defects
S	No defects	No defects
T	No defects	No defects

TABLE VII

Flexibility Test

Topcoat Formula	1/8 Inch Mandrel		1/4 Inch Mandrel	
	Unprimed	Primed	Unprimed	Primed
A	Lifted	Lifted	Lifted	Lifted
B	Lifted	Lifted	Lifted	Fine cracks and lifting
C	No defects	Very fine cracks	No defects	No defects
D	No defects	Very fine cracks	No defects	No defects
E	No defects	No defects	No defects	No defects
F	No defects	No defects	No defects	No defects
G	No defects	No defects	No defects	No defects
H	No defects	No defects	No defects	No defects
I	Lifted	Large cracks	Lifted	Medium cracks
J	Lifted	Medium cracks	Fine cracks	Fine cracks
K	No defects	No defects	No defects	No defects
L	No defects	No defects	No defects	No defects
M	No defects	No defects	No defects	No defects
N	No defects	No defects	No defects	No defects
O	Large cracks, lifting	Medium cracks	Large cracks, lifting	Fine cracks
P	Large cracks, lifting	Fine cracks	Large cracks, lifting	Fine cracks
Q	No defects	Fine cracks	No defects	No defects
R	No defects	Fine cracks	No defects	No defects
S	No defects	No defects	No defects	No defects
T	No defects	No defects	No defects	No defects

TABLE VIII

Humidity Cycle

Topcoat Formula	Condition Upon Removal
A	
A	No defects
B	No defects
C	No defects
D	No defects
E	No defects
F	No defects
G	No defects
H	No defects
I	No defects
J	No defects
K	No defects
L	No defects
M	No defects
N	No defects
O	No defects
P	No defects
Q	No defects
R	No defects
S	No defects
T	No defects

TABLE IX

Diester Immersion, 250°F

Topcoat Formula	Condition Upon Removal
A	Slight yellowing, no other defects
B	No defects
C	No defects
D	No defects
E	Film soft, yellow, poor adhesion to primer
F	Film soft, trace of blisters, poor adhesion to primer
G	Not tested
H	Not tested
I	No defects
J	No defects
K	Film soft, yellow, poor adhesion to primer
L	Film soft, medium blisters ASTM size #8, poor adhesion
M	Not tested
N	Not tested
O	No defects
P	No defects
Q	Film soft, yellow, poor adhesion to primer
R	Film soft, dense blisters, ASTM size #8, poor adhesion
S	Not tested
T	Not tested

TABLE X

Hydraulic Fluid Immersions

Topcoat Formula	MIL-H-5606B	MIL-H-19457B	MIL-H-22072
A	No defects	No defects	No defects
B	No defects	No defects	No defects
C	No defects	No defects	No defects
D	No defects	No defects	No defects
E	Slight softening, pink discoloration	Slight yellowing	Moderate softening slight yellowing
F	Slight softening	No defects	Moderate softening
I	No defects	No defects	No defects
J	No defects	No defects	No defects
K	Slight softening, pink discoloration	Slight yellowing	Moderate softening, slight yellowing
L	Slight softening	No defects	Moderate softening
O	No defects	No defects	No defects
P	No defects	No defects	No defects
R	Slight softening, pink discoloration	Slight softening	Moderate softening
S	Slight softening	No defects	Moderate softening

TABLE XI

Immersion Tests

Topcoat Formula	Sodium Hydroxide, 5% Time Immersed	Sodium Hydroxide, 5% Condition Upon Removal	Hydrochloric Acid, 5% Time Immersed	Hydrochloric Acid, 5% Condition Upon Removal	Methyl Isobutyl Ketone Time Immersed	Methyl Isobutyl Ketone Condition Upon Removal
A	30 days	No defects	30 days	No defects	30 days	Considerable softening
B	30 days	No defects	30 days	No defects	30 days	Considerable softening
C	30 days	No defects	30 days	No defects	30 days	No defects
D	30 days	No defects	30 days	No defects	30 days	No defects
E	30 days	No defects	30 days	Surface haze, no other defects	30 days	Considerable softening
F	30 days	No defects	30 days	Surface haze, no other defects	30 days	Considerable softening
I	30 days	No defects	30 days	No defects	30 days	No defects
J	30 days	No defects	30 days	No defects	30 days	No defects
K	168 hrs	Dense blisters, ASTM size #8	30 days	No defects	30 days	Considerable softening
L	30 days	No defects	30 days	No defects	30 days	Considerable softening
O	168 hrs	Medium blisters, ASTM size #8	30 days	Dense blisters, ASTM size #8	30 days	No defects
P	168 hrs	Medium blisters, ASTM size #8	30 days	Dense blisters, ASTM size #8	30 days	No defects
Q	168 hrs	Dense blisters, ASTM size #6	30 days	Dense blisters, ASTM size #2	30 days	Considerable softening
R	168 hrs	Dense blisters, ASTM size #6	30 days	Dense blisters, ASTM size #2	30 days	Considerable softening

TABLE XII

Gloss Determinations

Topcoat Formula	Gloss Geometry	Time Admixed 1/2 Hour	1 Hour	2 Hours	3 Hours	4 Hours	5 Hours	6 Hours	7 Hours
C	60°	95.0	95.0	95.0	95.0	95.0	95.0	95.0	95.0
	20°	95.0	95.0	94.0	94.0	95.0	95.0	92.0	92.0
D	60°	93.0	93.0	93.0	93.0	92.0	91.0	91.0	88.0
	20°	90.0	88.0	85.0	82.0	75.0	71.0	64.0	64.0
E	60°	81.0	80.0	63.0	62.0	67.0	74.0	90.0[1]	85.0
	20°	35.0	35.0	17.0	12.0	16.0	21.0	62.0	50.0
F	60°	60.0	68.0	80.0[1]	74.0	74.0	72.0	74.0	72.0
	20°	15.0	24.0	37.0	23.0	30.0	25.0	37.0	31.0
I	60°	66.0	68.0	64.0	60.0	57.0	57.0	52.0	48.0
J	60°	21.0	20.0	14.0	13.0	11.0	9.0	8.5	8.5
K	60°	14.0	13.0	13.0	12.5	12.5	12.0	12.0	12.0
L	60°	20.0	18.0	16.0	15.0	14.0	13.0	13.0	13.0
O	60°	3.0	3.0	2.8	2.8	2.8	2.8	2.7	2.5
P	60°	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q	60°	2.4	2.0	2.0	2.0	2.0	2.0	2.0	2.0
R	60°	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[1] Reduced 2 to 1 with xylene by volume.

TABLE XIII

Weatherometer Exposure

Topcoat Formula	Initial Values			Hours Exposed	After Exposure			Chalk ASTM No.	Units Loss, 60°	ΔL	Units Loss, 20°
	60°	45°	20°		60°	45°	20°				
A	97.0	86.0	100.0	168	94.0	80.7	81.0	10	3.0	- 2.9	19.0
				500	26.0	81.2	3.0	8	71.0	- 1.6	97.0
				1000	14.0	83.2	0.0	4	83.0	- 1.5	100.0
				2000	8.0	82.0	0.0	2	89.0	- 2.2	100.0
B	96.0	2.1	94.0	168	71.0	2.3	49.0	10	25.0	+ 0.7	45.0
				500	12.0	5.0	4.0	9	84.0	+ 7.9	84.0
				1000	0.0	5.2	0.0	4	96.0	+ 8.3	94.0
				2000	0.0	6.1	0.0	2	96.0	+10.2	94.0
C	95.0	87.0	90.0	168	90.0	86.6	76.0	10	5.0	- 0.2	14.0
				500	69.0	86.3	55.0	8	26.0	- 0.4	35.0
				1000	57.0	86.3	30.0	8	38.0	- 0.4	60.0
				2000	34.0	84.5	8.0	6	61.0	- 2.0	82.0
D	95.0	2.3	91.0	168	93.0	2.4	67.0	10	2.0	+ 0.3	24.0
				500	85.0	2.6	63.0	9	10.0	+ 1.0	28.0
				1000	72.0	2.9	43.0	8	23.0	+ 1.9	48.0
				2000	49.0	3.5	18.0	7	46.0	+ 3.5	73.0
E	88.0	87.0	64.0	168	82.0	86.3	49.0	10	6.0	- 0.4	15.0
				500	48.0	86.4	14.0	8	40.0	- 0.3	50.0
				1000	26.0	86.7	3.0	8	62.0	- 0.2	61.0
				2000	10.0	87.0	0.0	6	78.0	+ 0.5	64.0
F	84.0	2.4	50.0	168	79.0	2.6	42.0	10	5.0	+ 0.6	8.0
				500	65.0	2.7	25.0	9	19.0	+ 0.9	25.0
				1000	52.0	3.0	14.0	8	32.0	+ 1.8	36.0
				2000	14.0	5.5	1.0	6	70.0	+ 8.0	49.0
G	88.0	87.5	70.0	168	82.0	86.1	46.0	10	6.0	- 0.8	24.0
				500	57.0	85.4	19.0	8	31.0	- 1.1	51.0
				1000	32.0	84.8	5.0	7	56.0	- 1.5	65.0
				2000	15.0	83.2	1.0	6	73.0	- 2.3	69.0
H	88.0	2.1	74.0	168	89.0	2.2	40.0	10	-	+ 0.3	34.0
				500	63.0	2.6	24.0	9	25.0	+ 1.6	50.0
				1000	56.0	3.0	15.0	8	32.0	+ 2.8	59.0
				2000	10.0	5.0	0.0	6	78.0	+ 7.8	74.0

TABLE XIII - (Continued)

Topcoat Formula	Initial Values			Hours Exposed	After Exposure			Chalk ASTM No.	Units Loss, 60°	ΔL	Units Loss, 20°
	60°	45°	20°		60°	45°	20°				
I	70.0	84.3	-	168	56.0	83.4	-	10	14.0	- 0.5	-
				500	40.0	83.4	-	8	30.0	- 0.5	-
				1000	37.0	83.3	-	8	33.0	- 0.6	-
				2000	21.0	81.8	-	7	49.0	- 1.4	-
J	70.0	3.1	-	168	68.0	3.3	-	10	2.0	+ 0.6	-
				500	60.0	3.4	-	9	10.0	+ 0.8	-
				1000	56.0	3.5	-	8	14.0	+ 1.1	-
				2000	35.0	4.7	-	7	35.0	+ 4.1	-
K	13.5	83.0	-	168	8.0	83.9	-	10	5.5	+ 0.5	-
				500	5.0	83.9	-	8	8.5	+ 0.5	-
				1000	5.0	83.9	-	8	8.5	+ 0.5	-
				2000	3.5	82.0	-	7	10.0	- 0.6	-
L	20.0	3.3	-	168	20.0	3.6	-	9	-	+ 0.8	-
				500	15.0	3.9	-	8	5.0	+ 1.6	-
				1000	14.0	4.3	-	8	6.0	+ 2.6	-
				2000	6.0	6.6	-	6	14.0	_ 7.5	-
M	15.0	82.0	-	168	11.0	81.8	-	8	4.0	- 0.1	-
				500	8.0	81.5	-	8	7.0	- 0.3	-
				1000	5.0	81.2	-	7	10.0	- 0.4	-
				2000	5.0	78.1	-	7	10.0	- 2.2	-
N	21.0	2.6	-	168	15.0	3.0	-	9	6.0	+ 1.2	-
				500	13.0	3.5	-	8	8.0	+ 2.6	-
				1000	6.5	4.4	-	8	14.5	+ 4.9	-
				2000	3.5	6.5	-	7	17.5	+ 9.4	-

TABLE XIII - (Continued)

Topcoat Formula	Initial Values			Hours Exposed	After Exposure			Chalk ASTM No.	Units Loss, 60°	ΔL	Units, 85°
	60°	45°	85°		60°	45°	85°				
O	3.5	87.0	18.0	168	4.0	87.4	32.0	8	0.5	+ 0.2	+14.0
				500	3.0	87.1	31.0	8	0.5	+ 0.1	+13.0
				1000	3.5	84.6	32.0	8	-	- 1.3	+14.0
				2000	3.0	81.0	24.0	8	0.5	- 3.3	+ 6.0
P	0.5	9.7	14.0	168	1.0	9.6	23.0	8	0.5	- 0.2	+ 9.0
				500	1.0	9.6	25.0	8	0.5	- 0.2	+11.0
				1000	1.0	9.2	24.0	7	0.5	- 0.8	+10.0
				2000	1.0	10.0	24.0	7	0.5	+ 0.5	+10.0
Q	3.5	85.0	10.0	168	3.0	87.6	19.0	8	0.5	+ 1.	+ 9.0
				500	3.0	87.3	17.0	8	0.5	+ 1.2	+ 7.0
				1000	3.0	86.9	23.0	7	0.5	+ 1.0	+13.0
				2000	3.0	86.6	17.0	6	0.5	+ 0.9	+ 7.0
R	4.0	8.6	12.0	168	0.5	9.7	11.0	9	3.5	+ 1.8	- 1.0
				500	0.0	9.3	12.0	8	4.0	+ 1.2	-
				1000	0.0	10.3	12.0	7	4.0	+ 2.8	-
				2000	0.0	12.0	15.0	6	4.0	+ 5.3	+ 3.0
S	2.0	85.5	2.5	168	2.0	83.9	5.0	8	-	- 0.9	+ 2.5
				500	2.5	83.8	6.0	8	0.5	- 0.9	+ 3.5
				1000	2.0	81.5	7.0	7	-	- 2.2	+ 4.5
				2000	2.0	76.7	5.0	6	-	- 4.9	+ 2.5
T	0.0	8.6	1.0	168	0.0	7.9	2.5	8	-	- 1.2	+ 1.5
				500	0.0	7.9	3.0	8	-	- 1.2	+ 2.0
				1000	0.0	7.6	4.0	7	-	- 1.8	+ 3.0
				2000	0.0	8.7	3.0	6	-	+ 0.2	+ 2.0

TABLE XIV

Exterior Exposure, Panama Open Field Site

Topcoat Formula	Initial Values			Time Exposed, months	After Exposure			Chalk ASTM No.	Units Loss, 60°	ΔL	Units Loss, 20°
	60°	45°	20°		60°	45°	20°				
A	97.0	86.0	100.0	7	6.5	82.7	0.0	5	90.5	- 1.8	100.0
				13	3.5	81.2	0.0	2	93.5	- 2.6	100.0
				22	2.5	81.0	0.0	2	94.5	- 2.7	100.0
B	96.0	2.1	94.0	7	0.0	5.3	0.0	6	96.0	+ 8.5	94.0
				13	0.0	5.7	0.0	2	96.0	+ 9.4	94.0
				22	0.0	6.8	0.0	2	96.0	+11.6	94.0
C	95.0	87.0	90.0	7	85.0	87.2	73.0	9	10.0	+ 0.1	17.0
				13	49.0	87.8	15.0	8	46.0	+ 0.4	75.0
				22	10.0	87.5	0.0	4	85.0	+ 0.3	90.0
D	95.0	2.3	91.0	7	91.0	2.3	87.0	9	4.0	0.0	4.0
				13	60.0	3.4	19.0	8	35.0	+ 3.3	72.0
				22	23.0	5.2	0.0	4	72.0	+ 7.6	91.0
E	88.0	87.0	64.0	7	42.0	87.3	5.5	6	46.0	+ 0.7	58.5
				13	27.0	90.0	1.0	4	61.0	+ 1.6	63.0
				22	18.0	89.2	0.0	3	70.0	+ 1.2	64.0
F	84.0	2.4	50.0	7	48.0	3.2	8.0	6	36.0	+ 2.4	42.0
				13	27.0	4.7	1.0	4	57.0	+ 6.2	49.0
				22	6.5	6.9	0.0	2	77.5	+10.8	50.0
G	88.0	87.5	70.0	7	49.0	87.3	6.0	8	39.0	- 0.1	62.0
				13	25.0	88.1	1.0	5	63.0	+ 0.3	69.0
				22	13.0	86.7	0.0	4	88.0	- 0.4	70.0
H	88.0	2.1	74.0	7	70.0	2.6	25.0	8	18.0	+ 1.6	49.0
				13	16.0	5.0	0.0	6	72.0	+ 7.8	74.0
				22	2.5	6.9	0.0	4	85.5	+11.8	74.0
I	70.0	84.3	-	7	55.0	83.9	-	8	15.0	- 0.2	-
				13	34.0	85.3	-	8	36.0	+ 0.5	-
				22	8.5	84.5	-	4	61.5	+ 0.3	-
J	70.0	3.1	-	7	67.0	3.2	-	8	3.0	+ 0.3	-
				13	45.0	4.7	-	8	25.0	+ 4.1	-
				22	9.5	7.0	-	5	60.5	+ 8.9	-

TABLE XIV - (Continued)

Topcoat Formula	Initial Values			Time Exposed, months	After Exposure			Chalk ASTM No.	Units Loss 60°	ΔL	Units Loss 20°
	60°	45°	20°		60°	45°	20°				
K	13.5	83.0	-	7	6.0	83.1	-	6	7.5	+ 0.1	-
				13	4.5	84.0	-	4	9.0	+ 0.6	-
				22	3.0	83.0	-	2	10.5	0.0	-
L	20.0	3.3	-	7	10.0	4.4	-	7	10.0	+ 2.8	-
				13	5.0	6.3	-	6	15.0	+ 6.9	-
				22	0.0	8.8	-	4	20.0	+11.5	-
M	15.0	82.0	-	7	6.0	82.5	-	7	9.0	+ 0.3	-
				13	3.5	82.9	-	5	11.5	+ 0.5	-
				22	3.0	81.0	-	2	12.0	- 0.6	-
N	21.0	2.6	-	7	7.0	4.4	-	7	13.0	+ 4.9	-
				13	1.0	6.1	-	6	20.0	+ 7.6	-
				22	0.0	8.4	-	4	21.0	+12.7	-

Topcoat Formula	Initial Values			Time Exposed, months	After Exposure			Chalk ASTM No.	Units, 60°	ΔL	Units, 85°
	60°	45°	85°		60°	45°	85°				
O	3.5	87.0	18.0	7	3.0	86.8	36.0	6	-0.5	-0.1	+18.0
				13	2.5	86.9	21.0	5	-1.0	-0.1	+ 3.0
				22	2.5	86.5	18.0	2	-1.0	-0.3	0.0
P	0.5	9.7	14.0	7	1.5	10.0	30.0	6	+1.0	+0.5	+16.0
				13	1.0	11.3	25.0	5	+0.5	+2.5	+11.0
				22	0.0	13.0	21.0	3	-0.5	+5.9	+ 7.0
Q	3.5	85.0	10.0	7	3.0	83.8	19.0	5	-0.5	-1.7	+ 9.0
				13	2.5	84.1	13.0	2	-1.0	-0.5	+ 3.0
				22	2.5	84.0	10.0	2	-1.0	-0.5	0.0
R	4.0	8.6	12.0	7	1.5	9.5	17.0	6	-2.5	+1.5	+ 5.0
				13	0.0	9.9	5.0	4	-4.0	+2.1	- 7.0
				22	0.0	12.8	12.0	3	-4.0	+6.5	0.0
S	2.0	85.5	2.5	7	2.5	84.3	7.0	6	+0.5	-0.7	+ 4.5
				13	2.0	84.1	7.0	4	0.0	-0.8	+ 4.5
				22	2.0	83.0	6.5	2	0.0	-1.4	+ 4.0
T	0.0	8.6	1.0	7	0.0	8.4	4.0	6	0.0	-0.4	+ 3.0
				13	0.0	10.0	4.0	4	0.0	+2.3	+ 3.0
				22	0.0	11.7	8.5	3	0.0	+4.9	+ 7.5

TABLE XV

Exterior Exposure, Aberdeen Proving Ground, Maryland

Topcoat Formula	Initial Values			Time Exposed, months	After Exposure			Chalk ASTM No.	Units Loss 60°	ΔL	Units Loss 20°
	60°	45°	20°		60°	45°	20°				
A	87.0	86.0	100.0	6	13.0	83.0	0.0	6	84.0	-1.6	100.0
				13	8.5	83.1	0.0	4	88.5	-1.6	100.0
				25	3.5	82.2	0.0	2	93.5	-2.1	100.0
B	96.0	2.1	94.0	6	0.0	5.3	0.0	6	96.0	+8.5	94.0
				13	0.0	5.1	0.0	4	96.0	+8.1	94.0
				25	0.0	5.2	0.0	2	96.0	+8.3	94.0
C	95.0	87.0	90.0	6	92.0	87.1	80.0	9	3.0	+0.1	10.0
				13	86.0	87.0	67.0	8	9.0	0.0	23.0
				25	43.0	87.5	18.0	6	52.0	+0.3	72.0
D	95.0	2.3	91.0	6	93.0	2.3	91.0	9	2.0	0.0	0.0
				13	92.0	2.5	80.0	8	3.0	+0.6	11.0
				25	73.0	2.8	34.0	7	22.0	+1.6	57.0
E	88.0	87.0	64.0	6	34.0	87.0	4.0	6	54.0	0.0	60.0
				13	28.5	89.0	2.0	5	58.5	+1.1	62.0
				25	26.0	88.4	1.0	3	62.0	+0.8	63.0
F	84.0	2.4	50.0	6	56.0	3.3	15.0	6	28.0	+2.7	35.0
				13	48.0	3.5	10.0	5	36.0	+3.2	40.0
				25	21.0	4.1	0.0	3	63.0	+6.0	50.0
G	88.0	87.5	70.0	6	73.0	84.4	42.0	8	15.0	-1.7	28.0
				13	51.0	86.4	13.0	8	37.0	-0.6	57.0
				25	21.0	88.3	0.0	6	67.0	+0.4	70.0
H	88.0	2.1	74.0	6	77.0	2.2	47.0	8	11.0	+0.3	27.0
				13	75.0	2.4	44.0	8	13.0	+1.0	30.0
				25	46.0	4.1	6.0	6	42.0	+5.8	68.0
I	70.0	84.3	-	6	62.0	84.1	-	8	8.0	-0.1	-
				13	56.0	84.6	-	8	14.0	+0.2	-
				25	30.0	84.7	-	6	40.0	+0.2	-
J	70.0	3.1	-	6	70.0	3.1	-	7	0.0	0.0	-
				13	67.0	3.4	-	7	3.0	+0.8	-
				25	54.0	4.1	-	6	16.0	+2.6	-

TABLE XV - (Continued)

Topcoat Formula	Initial Values			Time Exposed, months	After Exposure			Chalk ASTM No.	Units Loss 60°	ΔL	Units Loss 20°
	60°	45°	20°		60°	45°	20°				
K	13.5	83.0	-	6	6.0	83.8	-	5	7.5	+0.4	-
				13	6.0	84.2	-	5	7.5	+0.7	-
				25	4.5	83.7	-	3	9.0	+0.4	-
L	20.0	3.3	-	6	13.0	4.3	-	6	7.0	+2.6	-
				13	12.0	5.0	-	5	8.0	+4.2	-
				25	3.5	6.4	-	4	16.5	+7.1	-
M	15.0	82.0	-	6	9.0	82.0	-	6	6.0	0.0	-
				13	6.5	82.4	-	5	8.5	+0.2	-
				25	3.5	82.5	-	4	11.5	+0.3	-
N	21.0	2.6	-	6	14.0	4.4	-	6	7.0	+4.9	-
				13	11.0	3.7	-	5	10.0	+3.1	-
				25	4.0	5.6	-	4	17.0	+7.5	-

Topcoat Formula	Initial Values			Time Exposed months	After Exposure			Chalk ASTM No.	Units, 60°	ΔL	Units 85°
	60°	45°	85°		60°	45°	85°				
O	3.5	87.0	18.0	6	3.5	85.6	33.0	5	0.0	-0.7	+15.0
				13	3.0	85.5	29.0	4	-0.5	-0.8	+11.0
				25	3.0	86.3	23.0	2	-0.5	-0.4	+ 5.0
P	0.5	9.7	14.0	6	1.5	9.7	29.0	6	+1.0	0.0	+15.0
				13	1.5	9.4	29.0	5	+1.0	-0.5	+15.0
				25	1.0	10.4	23.0	4	+0.5	+1.1	+ 9.0
Q	3.5	85.0	10.0	6	2.0	82.1	3.0	4	-1.5	-1.6	- 7.0
				13	2.0	83.4	8.5	4	-1.5	-0.9	- 1.5
				25	2.0	79.0	7.5	2	-1.5	-3.3	- 2.5
R	4.0	8.6	12.0	6	1.5	9.4	7.5	5	-2.5	+1.3	- 4.5
				13	1.5	8.9	15.0	5	-2.5	+0.5	+ 3.0
				25	1.0	9.6	14.0	3	-3.0	+1.7	+ 2.0
S	2.0	85.5	2.5	6	2.5	83.0	6.0	6	+0.5	-1.5	+ 3.5
				13	2.5	83.2	5.0	5	+0.5	-1.2	+ 2.5
				25	2.5	83.4	5.0	3	+0.5	-1.2	+ 0.5
T	0.0	8.6	1.0	6	0.0	8.5	3.5	6	0.0	-0.2	+ 2.5
				13	0.0	7.9	3.0	5	0.0	-1.2	+ 2.0
				25	0.0	9.1	2.0	4	0.0	+0.7	+ 1.0

APPENDIX C

FIGURE 1 - Gloss Versus Exterior Exposure Time

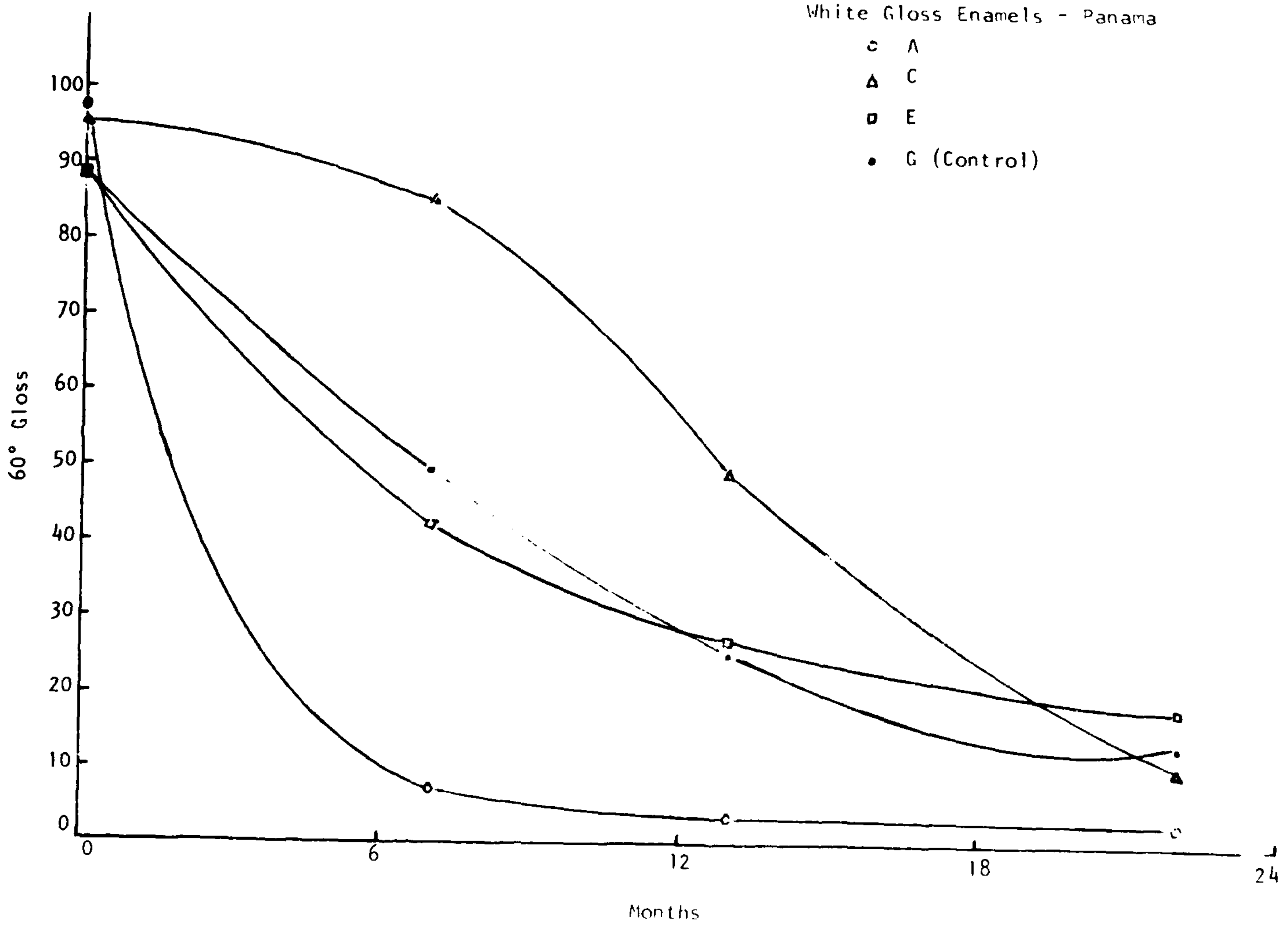


FIGURE 11 - Gloss Versus Exterior Exposure Time

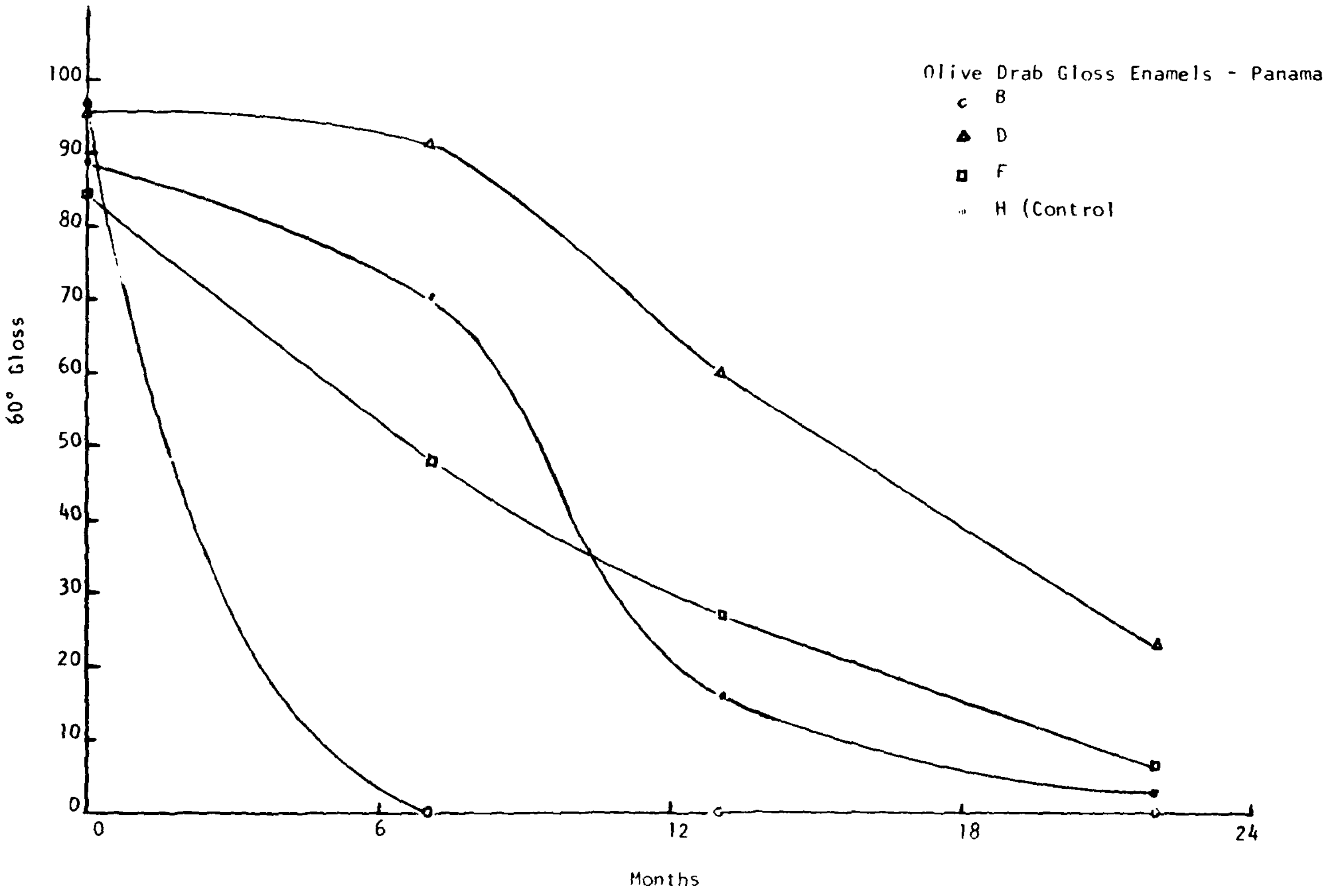


FIGURE III - Gloss Versus Exterior Exposure Time

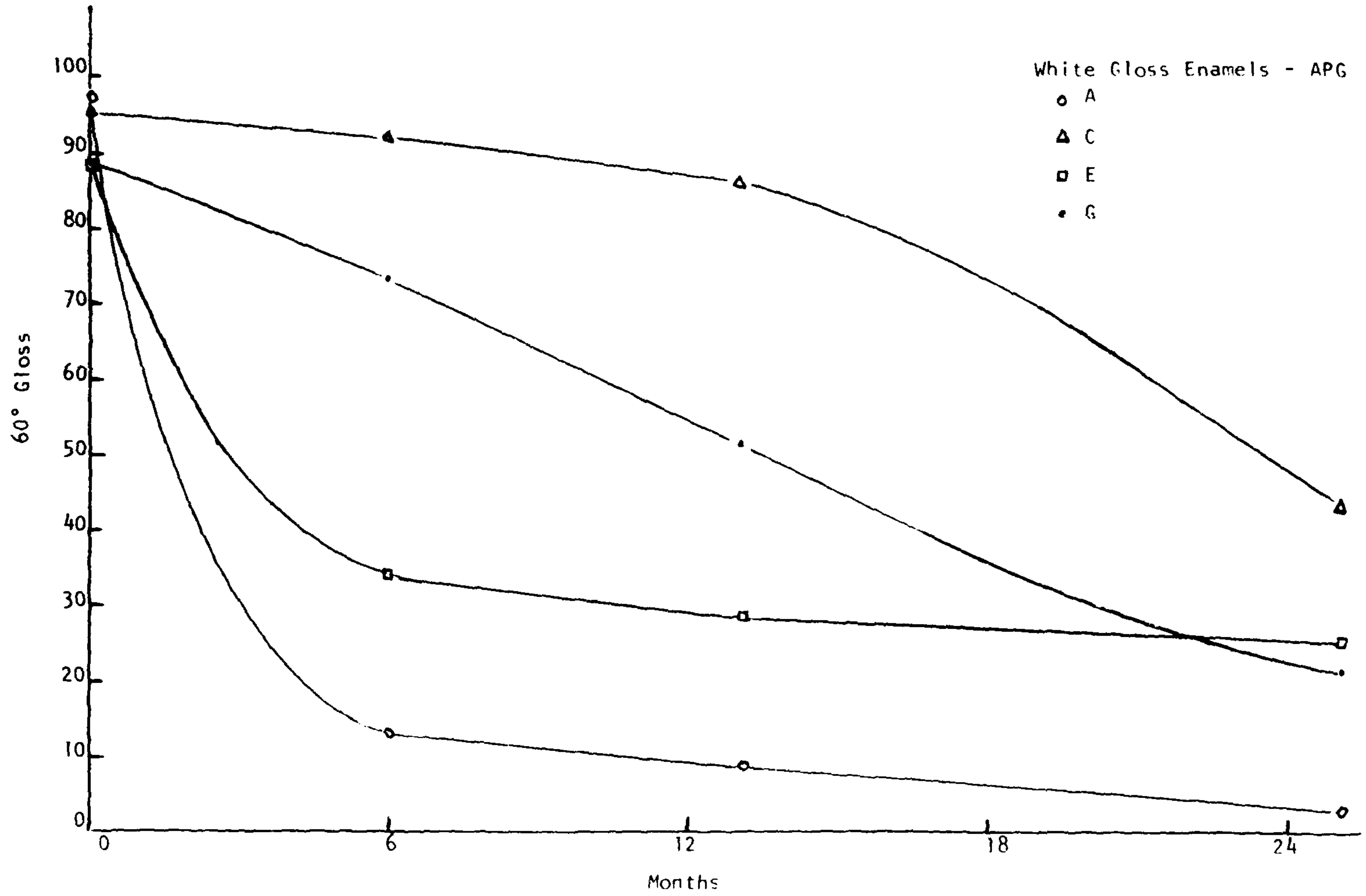
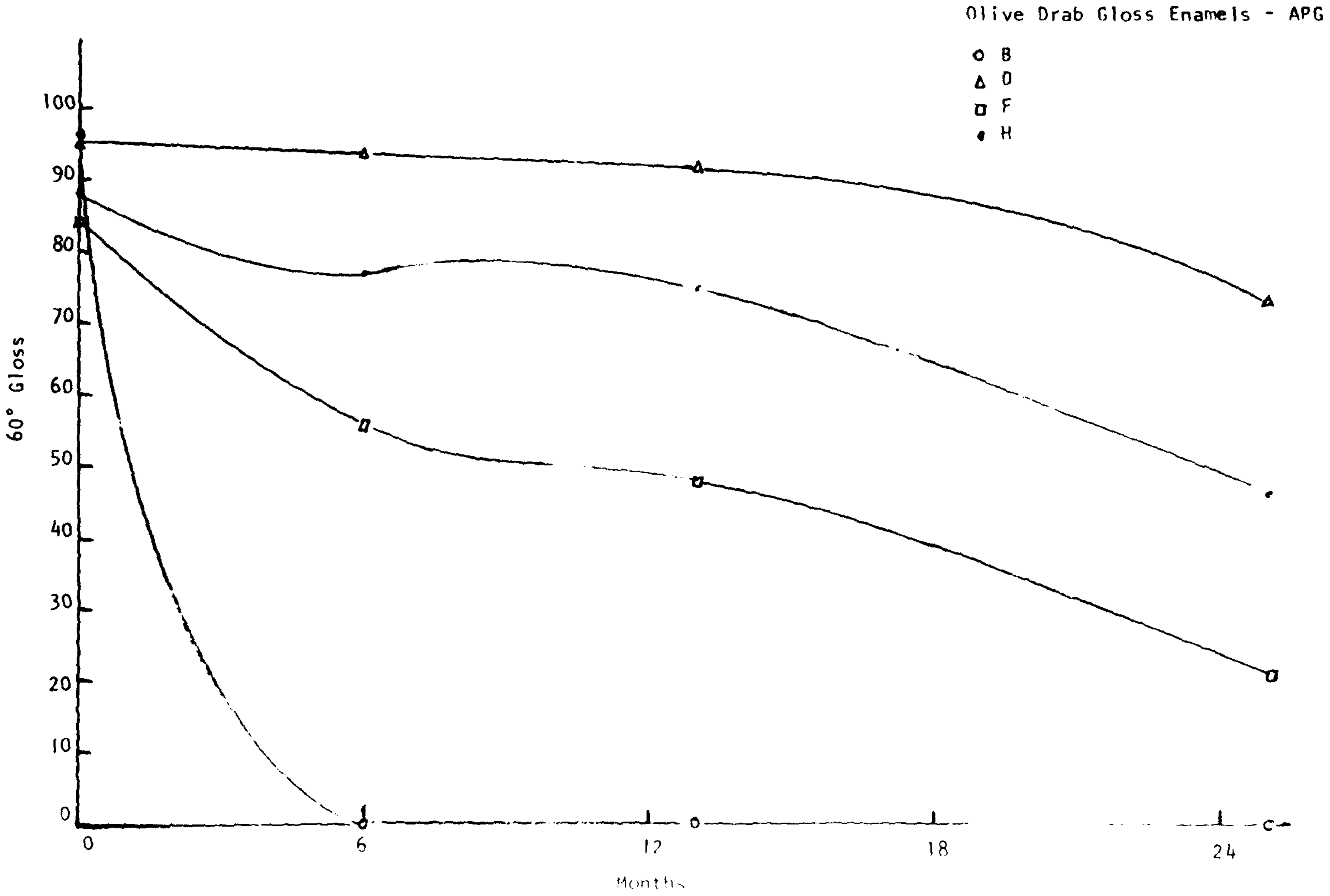


FIGURE IV - Gloss Versus Exterior Exposure Time



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13 ABSTRACT

Two package gloss, semi-gloss and lustreless coatings using an aliphatic diisocyanate cured polyurethane and a polyurea vehicle were formulated into white and olive drab colors. These finishes were evaluated for general performance in corrosion resistance, some chemical, hydraulic fluid and organic solvent resistance and weathering characteristics. The polyurethanes offer good protective and resistance properties and the alphatic diisocyanate cured polyurethanes have the additional advantage of extended gloss and color retention for exterior use as compared to aromatic cured urethanes and polyureas. However, water sensitivity and film brittleness may be a negative factor. The polyurea coatings offer less chemical and solvent resistance than the polyurethanes, but are more flexible and possess good water resistance. Exterior exposure properties are similar to alkyd type enamels.

UNCLASSIFIED

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Chemical Resistance Corrosion Resistance Water Resistance Flexibility Weathering Properties						

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