

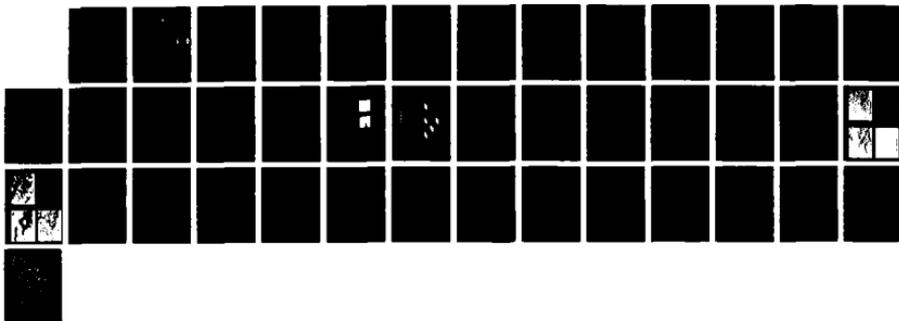
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CLEANABILITY OF AIRCRAFT POLYURETHANE TOPCOATS(U) NAVAL 1/1  
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**CLEANABILITY OF AIRCRAFT  
POLYURETHANE TOPCOATS**

Charles R. Hegedus and Donald J. Hirst

Air Vehicle and Crew Systems Technology Department  
NAVAL AIR DEVELOPMENT CENTER  
Warminster, PA 18974-5000

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<p>U.S. Navy operational tactical aircraft are painted with a camouflage, two component, aliphatic polyurethane which is the product of hexamethylene diisocyanate and a polyester polyol. This material conforms to military specification MIL-C-83286. One deficiency of this coating which is frequently reported by field activities is its poor cleanability. Navy aircraft are repainted approximately every 3 to 4 years. During their deployment, they are soiled constantly and cleaned approximately every two weeks. The gray lusterless topcoats used in the camouflage schemes often cannot be restored to their original color, even with standard aircraft cleaners. In addition, when the discolored topcoat is damaged and must be repaired, matching of the color is impossible for field touch-up.</p> <p>A test to evaluate coating cleanability has been utilized to determine the severity of this problem and recommend possible solutions. Several coatings on the MIL-C-83286 qualified products list were evaluated along with topcoats which contain polymer bead pigments. A distinct correlation was found between cleanability and 60° gloss. Topcoats with a gloss of less than 4 had significant color changes when soiled and cleaned; coatings with gloss values above 4 had color changes that were far less noticable even after 10 soiling/cleaning cycles. This</p>			
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effect is caused by the surface roughness required for low gloss coatings, which allows carbonaceous soil particulates to become entrapped in the coating surface. Coatings which were more hydrophilic, as determined by water contact angle, were more cleanable than those which were hydrophobic. This effect is attributed to the smoother surface of the hydrophilic coatings and the ability of the cleaner to wet these surfaces. It was also found that low gloss ( $\leq 3$ ) topcoats containing polymer beads were more cleanable than their conventionally pigmented counterparts. Scanning electron micrographs comparing the surfaces, illustrated that this is due to less voids and more rounded surface protrusions in the polymer bead coatings. Coatings which are cleaned shortly after application and cure were found to be significantly more cleanable than non-cleaned coatings. The pre-cleaning makes the surface more hydrophilic and may smooth out some of the surface irregularities without increasing gloss.

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## PREFACE

Under the Navy Exploratory Development Program for Airborne Materials, a project was undertaken to study the cleanability and weatherability of camouflage coating systems. The following is a phase report which discusses the cleanability of aircraft polyurethane topcoats. Analysis of the weatherability of these coatings is ongoing and will be addressed in a future report.

During this project, commercially available coatings which qualify under military specifications were analyzed. The discussion of these products in this report does not imply or otherwise constitute an endorsement by the authors or the U.S. Government.

## INTRODUCTION

Currently, Navy operational tactical aircraft are painted in multi-theater camouflage schemes designed to minimize optical detectability in a variety of world-wide engagement scenarios. These camouflage schemes normally consist of several shades of lusterless gray colors which closely match the aircraft's operational background visible reflectance and have a low specular reflectance. Figure 1 is a schematic of the F/A-18 camouflage scheme in the designated Federal Standard 595 colors. For comparison, Figure 2 illustrates the four shades of gray used in these schemes, along with white and black specimens.

Navy aircraft paint systems consist of an epoxy primer (MIL-P-23377 or MIL-P-85582) and a polyurethane topcoat (MIL-C-83286). The topcoat is a two component, aliphatic polyurethane which is the product of a polyester polyol and hexamethylene diisocyanate. Although this coating is chemical and weather resistant, two of the most significant problems encountered with aircraft paint systems are degradation of the coating and color change caused by ultraviolet radiation and carbonaceous soils. All organic coatings are susceptible to polymeric degradation caused by environmental exposure. UV radiation, high humidity, sea spray, and surface contaminants cause paints to crack, blister, debond, and change color. In addition, entrapped dirt can drastically change a coating's optical properties and even the most successful cleaners have been unable to restore these properties to these camouflage coatings. Degradation and color change of the paint system have several detrimental effects:

- (1) Corrosion of aircraft alloys, excluding mechanical damage, is significantly controlled by the integrity of the protective coating system (1).
- (2) Color change of the coating system may hinder the intended camouflage properties.
- (3) Matching topcoat colors during touch-up is difficult, making aircraft unsightly.

In order to minimize or eliminate these effects, this project was undertaken to:

- (1) Determine and analyze the effects of weathering and soiling/cleaning on the camouflage aircraft polyurethane topcoat, MIL-C-83286.



(2) Determine coating compositional, optical, mechanical, and surface properties which enhance weatherability and cleanability.

(3) Recommend possible formulation changes to improve coating performance.

This is a phase report which discusses the cleanability of aircraft polyurethane topcoats.

#### BACKGROUND DISCUSSION ON COLOR

One of the main objectives of this effort was to analyze changes in paints after soiling/cleaning. One such change is color. Although it is beyond the scope of this report to present details of color theory and principals, it is necessary to have a common basic knowledge of color and colorimetry. Color is defined as a psychological response to the physical stimulus of light, other than spatial and temporal inhomogeneities, by the retina of the eye (2). Colorimetry is the measurement and relative correlation of what is seen by the eye.

Color can be fully defined by three separate and distinct terms: lightness, hue, and saturation. Lightness is described as that characteristic of a color relating to the degree of whiteness/blackness. That is, the relative arrangement of the achromatic "lightness" characteristic of the color. For example, the lightness of achromatic grays is solely dependent on how dark they are. Hue is the attribute of a color by which it is perceived to be red, yellow, green, blue, purple, etc. White, black, and achromatic grays contain no hue. Saturation can be perceived as the pureness or deepness of a color. For example, fire engine red has a higher saturation than a dull, washed-out red. This description of color illustrates that three concepts or values are adequate to fully define a specific color.

There are several color order systems, the most common of which are the Munsell and the CIE systems. The Munsell system is a qualitative ordering of colors based on the above three concepts of lightness, hue, and chroma; it is a selection and ordering of various color samples as well as a physical description of these colors. The CIE system is a quantitative description of colors based on the concept that all colors can be obtained from the mixing of the three primary colors: red, green, and blue. These systems are fully described in the literature (3,4).

One modification of the CIE system is the L,a,b color coordinate system. It uses three numbers to quantify and define colors. Figure 3 is a graph illustrating how the three numbers are determined and represented. The L value is a measure of the lightness of the color where 0 is a pure black and 100 is a pure white. The "a" value is the red-green coordinate. When the value is positive, the sample is more red than green, whereas if it is negative, the sample is closer to a true green. The "b" value is the yellow-blue coordinate, negative values indicating a bluer color and positive values indicating a yellow color. By providing the L, a, and b values, a color is fully defined. One major advantage of this system, as illustrated in Figure 3, is the ease of perception of a given color from its Lab coordinates. This is especially true when describing or analyzing color differences. It is easier to envision a color difference when described as being whiter, bluer, redder, etc. Color

differences can be easily quantified by using these Lab coordinates. A dimensional difference, dE, on the color graph can be calculated by:

$$dE = \sqrt{(L_f - L_i)^2 + (a_f - a_i)^2 + (b_f - b_i)^2} \quad (1)$$

where L, a, and b are tricoordinate color values, normally obtained from a colorimeter; i and f denote the L, a, and b values prior to and after exposure and/or conditioning, respectively.

It must be noted that although this approach provides a quantitative value for color differences, the exact accuracy of this magnitude is dependent upon a number of complicated factors which include the actual perception and acuity of the observer, the wavelengths and intensity of light, and geometric factors. In addition, colors with the same dE values when compared to a standard can be extremely different. For example, one color may be lighter than the standard, thus having a higher L value, while another color may be the same lightness but much redder. The result may be the same dE with the two sample colors being totally different. Nonetheless, the importance of the above discussion is that the tricoordinate Lab system provides a quantitative description of colors and color differences with a consistent meaning in terms of visual perception. It has been stated that the average naked human eye can, in general, discern color differences with a dE greater than 1. Although this generalization does not indicate what is acceptable, it provides a base line for understanding the magnitude of how color differences are perceived.

## EXPERIMENTAL

### Materials

Table I is a list of the polyurethane topcoats analyzed during this investigation. Deft and DeSoto coatings are on the MIL-C-83286 qualified products list and, as such, are used extensively on Navy aircraft. The Camolite coating is similar to the MIL-C-83286, however it contains polymeric bead pigments. It is used as the finish coat on production F/A-18 aircraft and is specifically formulated with the beads to improve cleanability of the coating. The self-priming topcoat is an NADC developed material designed to replace the conventional primer and topcoat system. The formulation is listed in Appendix A and the material is further described in reference (5). The materials tested were primarily Federal Standard 595 colors: 35237, 36320, 36375, and 36495. In addition, several of these coatings were modified in-house to vary their gloss properties.

Specimens were prepared by applying 0.6 to 0.9 mils (15.2 to 22.9  $\mu$ m) of MIL-P-23377D epoxy primer to 2024 T-3 bare aluminum specimens which were cleaned and chromated with materials conforming to MIL-C-81706 to produce a chemical conversion coating meeting MIL-C-5541. The impact flexibility test specimens were 2024-O temper aluminum alloy, anodized in accordance with MIL-A-8625, Type 1. The dimensions of all specimens were 3 x 6 x 0.02 inches (7.62 x 15.24 x 0.05 cm). The two-component topcoats were prepared by mixing the components and allowing a 30 minute dwell time before application. The coatings were then applied to a dry film thickness of 2.0  $\pm$  0.2 mils (50.8  $\pm$  5.1  $\mu$ m). The self-

priming topcoat was applied directly to the metal surface without the use of a primer. The coatings were allowed to cure at ambient laboratory conditions for two weeks prior to testing. The dwell and cure times were selected after a preliminary testing program indicated that these times would provide consistent and realistic results.

Table I: POLYURETHANE TOPCOATS ANALYZED

<u>MANUFACTURER</u>	<u>MANUFACTURER'S CODE</u>	<u>FED. STD. 595 COLOR</u>
Deft	03-B2-73/03-BL-73	35237
Deft	03-GY-97/03-GY-97	36320
Deft	03-GY-98/03-GY-98	36375
Deft	03-GY-214/03-GY-214	36495
De Soto	826x377/910x376	35237
De Soto	822x362/910x376	36320
De Soto	822x363/910x376	36375
De Soto (CAMOLITE)	822x542/910x665	36320
De Soto (CAMOLITE)	822x544/910x665	36375
NADC	UB-14, Self-Priming Topcoat	35237

#### Test Procedures

The cleanability test was a modification of a proposed ASTM method devised to evaluate the cleaning efficiency of aircraft surface cleaners (6). Modifications to the procedure were made because the original method was devised to evaluate the efficiency of cleaners while the desired test in this study was for cleanability of coatings. The modified procedure is described in detail in Appendix B. This method has provided consistent and representative results relative to actual field experience. The soil was selected based on previous studies (7,8) which have indicated this soil to be representative of that found on operational aircraft.

Hardness, flexibility, color, and gloss of untreated and soiled/cleaned coatings were measured according to the procedures listed in Table II. The procedures used to determine film hardness were modifications of the listed ASTM methods. Although these methods were originally designed to test coating adhesion, they were modified slightly in this study to quantify and analyze film hardness. The modifications involved determination of the weight needed to scratch and mar the surface of the film.

Color values were measured using a MacBeth 1010S colorimeter. The color change due to soiling and cleaning was quantified using the  $dE$  value (equation 1) calculated prior to and after conditioning. In order to compare cleanability effects of different colors and since the soil was black and it primarily affected the L value, a normalized cleanability value, CLNORM, was calculated:

$$CLNORM = L_F/L_i$$

where  $L_i$  and  $L_f$  are the L values prior to and after cleaning.

Table II: TEST PROCEDURES

<u>PROPERTY</u>	<u>PROCEDURE</u>
Gloss, 60°	ASTM D 523
Color	ASTM D 2244
Adhesion (Hardness)	
Scrape	ASTM D2197 A
Microknife	ASTM D2197 B
Impact Flexibility	
G.E.	FTMS 141, 6226
Gardner	ASTM D2794

60 and 85 degree gloss values were according to ASTM D523 measured using a Glossgard II manufactured by Pacific Scientific. Although both 60° and 85° glosses are recommended for semi- and low-gloss finishes (9), 60 degree measurements are more commonly used for aircraft coatings. 85 degree measurements are used for low gloss materials to describe their sheen properties. During this investigation, the best correlations were found between 60 degree gloss values and cleanability. Unless otherwise stated, all gloss values are for 60 degree geometry. 85 degree gloss values were periodically measured to determine effects on camouflage properties which require low sheen.

The contact angle,  $\theta$ , of distilled water on the coatings' surface was measured at 70° F (21° C) and 50% relative humidity using a Rame-Hart contact angle goniometer, model 100.

## RESULTS AND DISCUSSION

Physical, optical, and surface properties of the 10 coatings tested are listed in Table III along with dE and CLNORM values obtained after the cleanability test. As illustrated in Figure 4, dE values for the materials tested range from 1.7, which is a barely noticeable color change, to 16.3, which is a drastic color change. This indicates that soiling of camouflage aircraft surfaces, even when cleaned with a standard aircraft cleaner, may cause significantly noticeable color changes. CLNORM was calculated to normalize the differences between colors in order to compare the cleanability of the various color coatings. However, in comparing CLNORM and dE (See Figure 5) for the 10 original coatings, there is a direct linear relationship. This relationship was confirmed by comparing dE and CLNORM (See Figure 6) for additional coatings evaluated during this study which are described later. Therefore, direct comparison of dE between coatings is valid.

Although no correlation could be found between impact flexibility or hardness with dE, gloss and contact angle had distinct effects on cleanability. Figures 7 and 8 illustrate dE versus gloss and contact angle, respectively. Figure 7 indicates an increase in dE, poor cleanability, as gloss is decreased. This is especially evident at low gloss values. In order to further quantify the effects of gloss on cleanability, the conventionally pigmented coatings listed in Table II (those not containing polymer beads) were modified to increase their gloss to varying degrees by adding clear isocyanate and polyester polyol resins to their formulations to increase polymer binder concentration,

TABLE III. POLYURETHANE TOPCOAT PROPERTIES

<u>COATING</u>	<u>CLNORM</u>	<u>dE</u>	<u>G.E. (% ELONG)</u>	<u>GARDNER (IN-LB)</u>	<u>MICRO (GRAMS)</u>	<u>SCRAPE (KGS)</u>	<u>GLOSS</u>	<u>θ (DEGREES)</u>
DEFT, 35237	91.9	4.51	60	65	300	750	1.6	90
DESOTO, 35237	96.0	2.35	20	30	400	1000	3.6	76
DEFT, 36320	98.4	1.23	60	70	300	500	5.7	74
DESOTO, 36320	76.5	13.07	10	5	300	1000	1.1	98
CAMOLITE, 36320	83.3	9.73	60	75	300	250	1.1	81
DEFT, 36375	97.9	1.70	60	80	350	750	5.0	75
DESOTO, 36375	73.1	16.31	5	5	400	500	1.2	90
CAMOLITE, 36375	81.7	11.29	60	80	250	250	1.2	82
DEFT, 36495	96.5	1.87	60	80	350	1000	6.1	78
NADC, PR/PC	90.3	6.20	20	15	100	250	4.8	77

decrease pigment concentration, and thus increase gloss. Figure 9 is a graph illustrating a wide range of gloss versus dE. The insert in the upper right hand corner clearly illustrates a critical gloss of approximately 4.0, below which the coatings drastically change color when soiled and cleaned. Difference in surface roughness is illustrated in scanning electron micrographs at 500X and 2000X in Figures 10 and 11, respectively. Figures 10a and 11a are Deft 36320 with a gloss of 5.7 and a dE of 1.23. Figures 10b and 11b are DeSoto 36320 with a gloss of 1.1 and dE of 13.07; Figures 10c and 11c are Camolite 36320 with a gloss of 1.1 and dE of 9.73. The gloss/dE relationship is easily explained considering that reduction in gloss is caused by increasing the surface roughness. The increased surface roughness can entrap carbonaceous particles which have a diameter of approximately 0.02 microns. Coatings with gloss values above 4 change color only slightly. Although "low" gloss coatings are required for camouflage purposes, it may be possible to have gloss requirements of between 4 and 7 to maintain camouflage properties while having a more cleanable and maintainable coating system.

Although it is difficult to mathematically describe the relationship between the contact angle of water and the dE obtained after cleanability (Figure 8), it is obvious that coatings with lower contact angle are more cleanable. It should be noted that lower water contact angles indicate the coating surface is more hydrophilic. This agrees with results from a previous study (7). In addition, rougher surfaces can often produce higher contact angles due to the geometry at the coating surface/water droplet interface. Therefore, coatings with lower water contact angles may be more cleanable for two reasons: (1) The cleaner can wet the hydrophilic surface and thus be more effective and/or (2) a smoother surface allows less dirt particulates to be entrapped.

The cleanability data of the original 10 topcoats (Table III and Figure 4) indicates that the Camolite coatings which contain polymer beads are more cleanable than the DeSoto conventionally pigmented coatings, even though they both have similar gloss values. For example, both 36320 coatings have gloss values of 1.1 with dE values of 9.73 and 13.07, respectively. Figures 10 and 11 illustrate that coatings with polymer beads have a smoother surface than the conventionally pigmented coatings with equivalent gloss. The polymer bead coating has surface irregularities which are rounded and somewhat uniform while the conventionally pigmented material appears more resin starved with voids in the surface where dirt can be entrapped. As noted earlier, the polymer bead material is manufactured specifically to improve cleanability. Other reports (10, 11, 12) also have claimed polymer bead aircraft topcoats are more cleanable than conventionally pigmented counterparts. In order to further study the polymer bead effect, both 36320 topcoats were modified to increase their gloss by adding clear resin to their formulations. The cleanability of these coatings was measured and Table IV compares the dE/gloss relationship. As this table indicates the polymer bead effect decreases as gloss increases. At a gloss of 3 and above, the effect is no longer prevalent.

The results presented and discussed above are on aircraft camouflage topcoats which have been soiled and cleaned once. Operational aircraft are normally re-painted approximately every 3 to 4 years and throughout this time period, they are continuously soiled and periodically cleaned (usually every 2 weeks). In order to simulate this condition, Deft, DeSoto, and Camolite 36320 coatings were soiled and cleaned for 10 cycles. In addition, other specimens of

these coatings were cleaned without soiling to determine if the cleaner or cleaning action had an effect on color change. The dE values were calculated after each cycle using the original Lab color values. The specimens which were cleaned without soiling had dE's of less than 0.55 after 10 cleanings, indicating that neither cleaner nor cleaning action had a significant effect on color change. Figure 12 illustrates the dE values for the 3 coatings after each soiling/cleaning cycle. The original gloss values of these coatings were 3.6, 1.2, and 1.3 for the Deft, DeSoto, and Camolite coatings, respectively. The gloss difference explains the better cleanability of the Deft coating over the other two, which is evident throughout the 10 soiling/cleaning cycles. Also, the Camolite coating, with polymer bead pigment, performed better than the DeSoto coating even though they both have equivalent gloss characteristics. At the end of the tenth cycle, the dE values were 7.08, 18.75, and 23.43, respectively. The dE's of the two low gloss coatings are extremely high and indicate drastic color changes. Although 7.08 indicates a noticeable color change, considering the 10 soiling and cleaning cycles, this may be acceptable; however, a color match of this coating during touch-up would be unlikely. It should be noted that for all three coatings, there was no significant change in either 60 or 85 degree gloss after the 10 soiling/cleaning cycles. In addition, SEMs at 500X and 2000X of these coatings showed no visual difference from the original surface.

Table IV: COMPARISON OF CLEANABILITY OF POLYMER BEAD AND CONVENTIONAL PIGMENT TOPCOATS

<u>GLOSS</u>	<u>CONVENTIONAL</u>	<u>dE</u>	<u>POLYMER BEAD</u>
1.1	13.07		9.73
2.8	4.63		--
3.1	--		4.42
15.6	--		1.39
37.6	0.69		--

The results indicate that surface topography and hydrophilicity have the most significant effects on coating cleanability. In an attempt to improve cleanability without effecting the gloss properties, the specimens which were cleaned without soil for 10 cycles were soiled and cleaned. It was believed that the cleaning action burnished the coating surface, making it smoother, without effecting the gloss. As indicated above, the gloss of the coatings did not change after the 10 cycles. The cleaning action also renders the coating surface more hydrophilic. Table V compares the cleanability of the virgin topcoats versus those that had been cleaned 10 times prior to soiling, along with the contact angle of water on these specimens. These results clearly indicate that the pre-cleaned specimens are more hydrophilic and more cleanable than the untreated, virgin topcoats. Therefore, pre-cleaning of aircraft after painting and prior to use may improve overall cleanability of the paint system. It should be noted from this data, that hydrophilic nature is not the sole criterion of cleanability.  $\theta$  for the untreated Deft coating is  $74^\circ$  with a resulting dE of 2.09 while  $\theta$  for the pre-cleaned Camolite is  $72^\circ$  with a dE of 6.13. Therefore, it is equally important to have a smoother surface, as well as a more hydrophilic surface.

Table V: CLEANABILITY OF PRE-CLEANED AND VIRGIN TOPCOATS

TOPCOAT	VIRGIN		PRE-CLEANED	
	dE	$\theta$	dE	$\theta$
DEFT	2.09	74	1.32	62
DESOTO	14.67	98	10.53	83
CAMOLITE	9.71	81	6.13	72

### CONCLUSIONS

1. Soiling of aircraft camouflage coatings causes significant color changes even after cleaning with a standard aircraft cleaner.
2. Gloss has a significant effect on cleanability. Coatings with a  $60^{\circ}$  gloss of less than 4 have drastic color changes when soiled and cleaned. This effect is magnified when the coatings are repeatedly soiled and cleaned.
3. The more hydrophilic a surface is, the more cleanable it will be.
4. Low gloss ( $\leq 3$ ) polymer bead coatings are more cleanable than their conventionally pigmented counterparts.
5. Coating surfaces which are cleaned after coating application and prior to soiling are more hydrophilic and more cleanable.

### RECOMMENDATIONS

1. Aircraft camouflage topcoats  $60^{\circ}$  gloss requirements should be between 4 and 7 to produce cleanable coating systems if survivability requirements do not dictate that this will detrimentally affect the mission of the aircraft.
2. Aircraft should be cleaned one or two days after paint system application to improve cleanability of the coating system.
3. If low gloss ( $\leq 3$ ) must be utilized, polymer bead coatings should be applied because of their improved cleanability over conventionally pigmented coatings.

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#### ACKNOWLEDGEMENT

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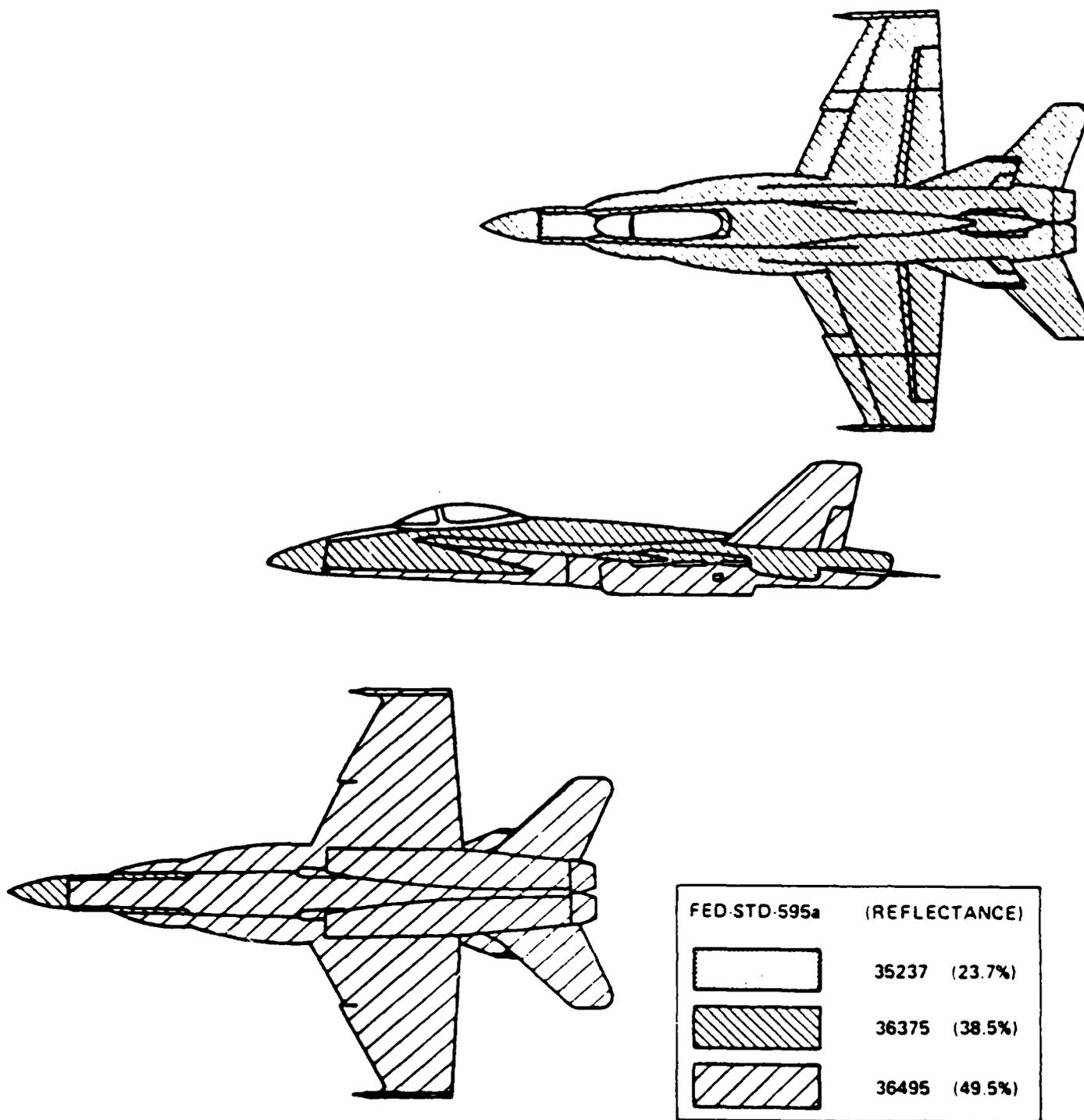
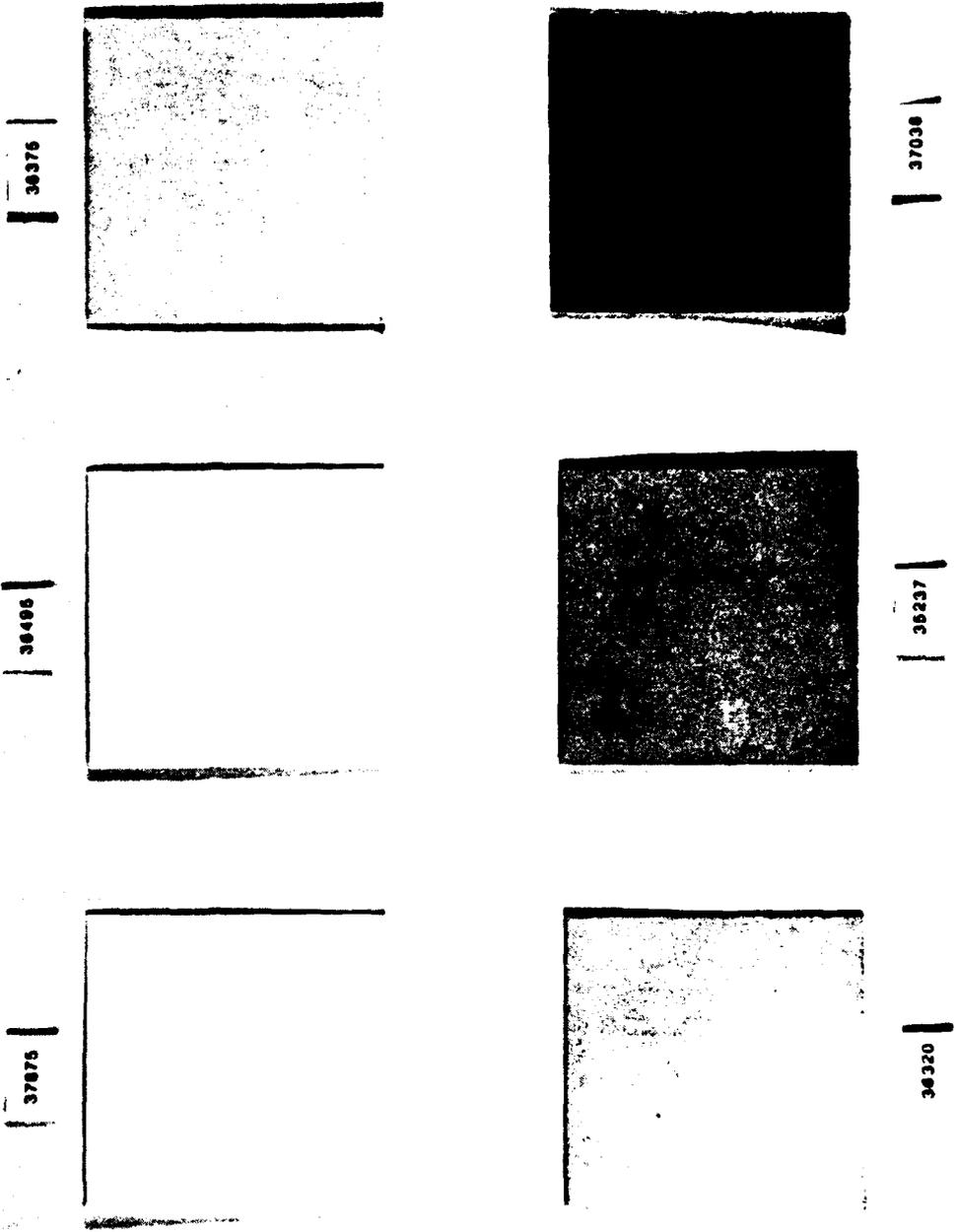


Figure 1 Schematic of F/A-18 Multi-Theater Camouflage Scheme

**PAINT COLORS**



FEDERAL STANDARD 595 COLOR NUMBERS

Figure 2 Multi-Theater Camouflage Scheme Colors

# L,a,b, COLOR SOLID

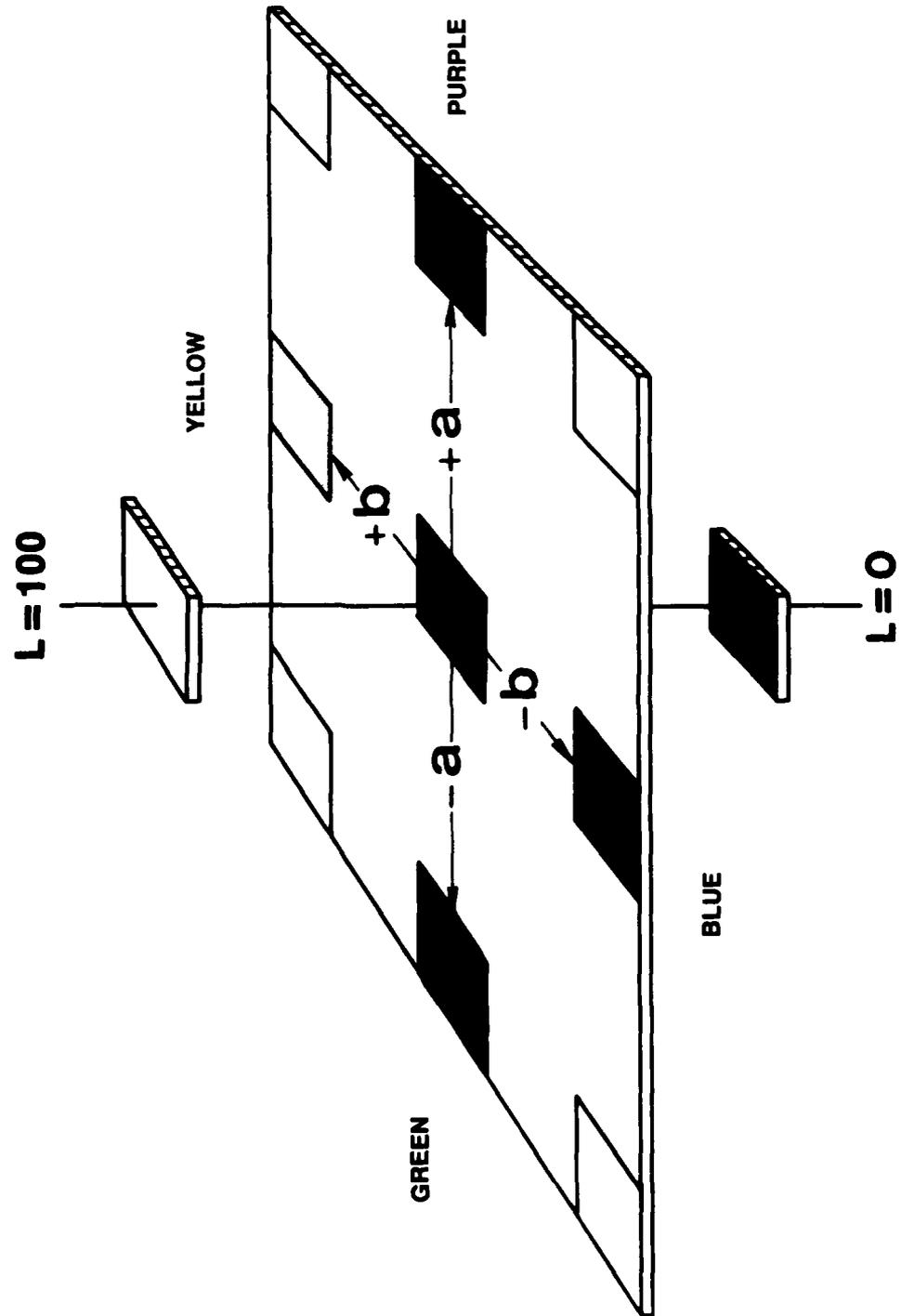


Figure 3 L,a,b Color Graph

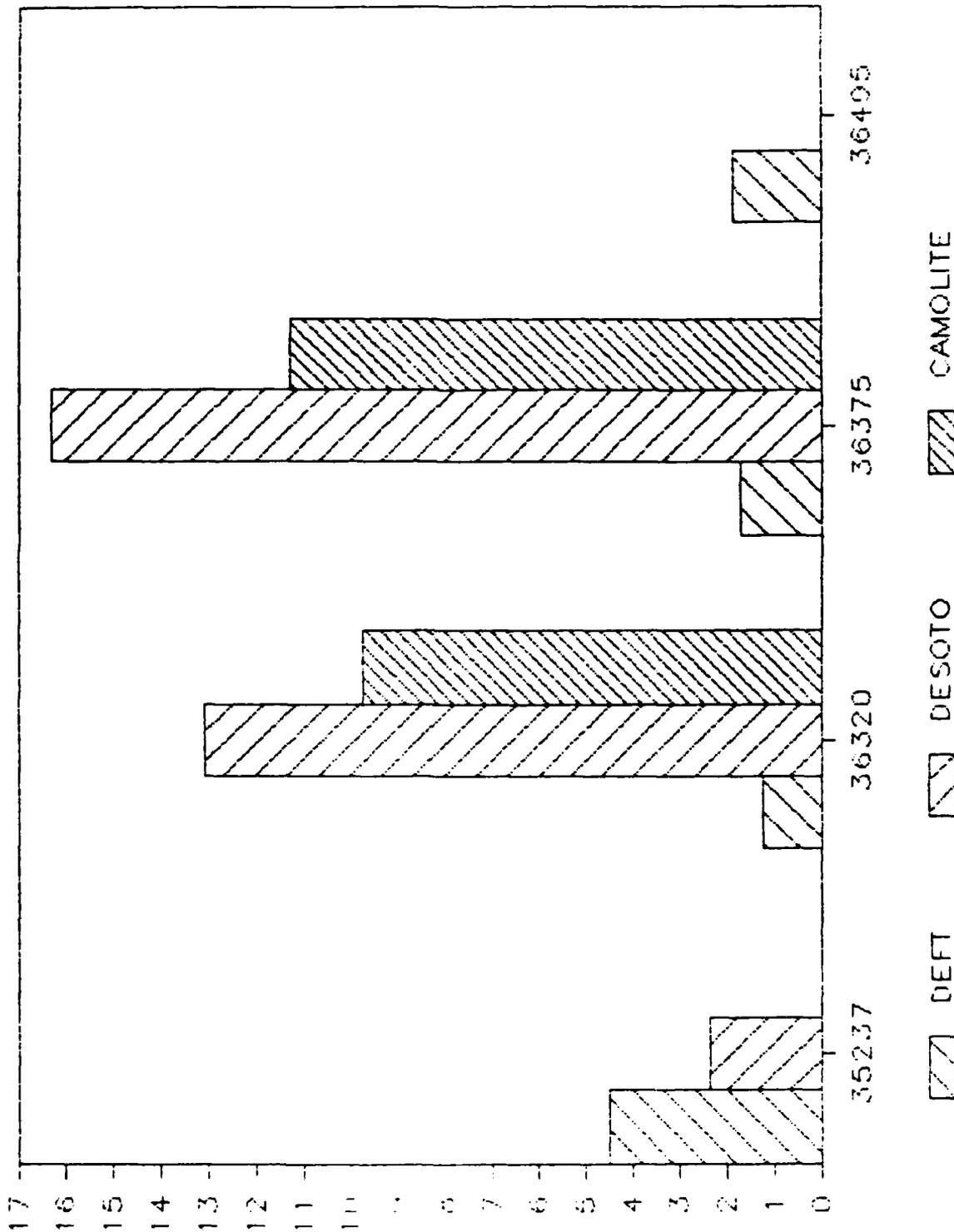


Figure 4 dE of Aircraft Polyurethane Topcoats After Cleanability Test

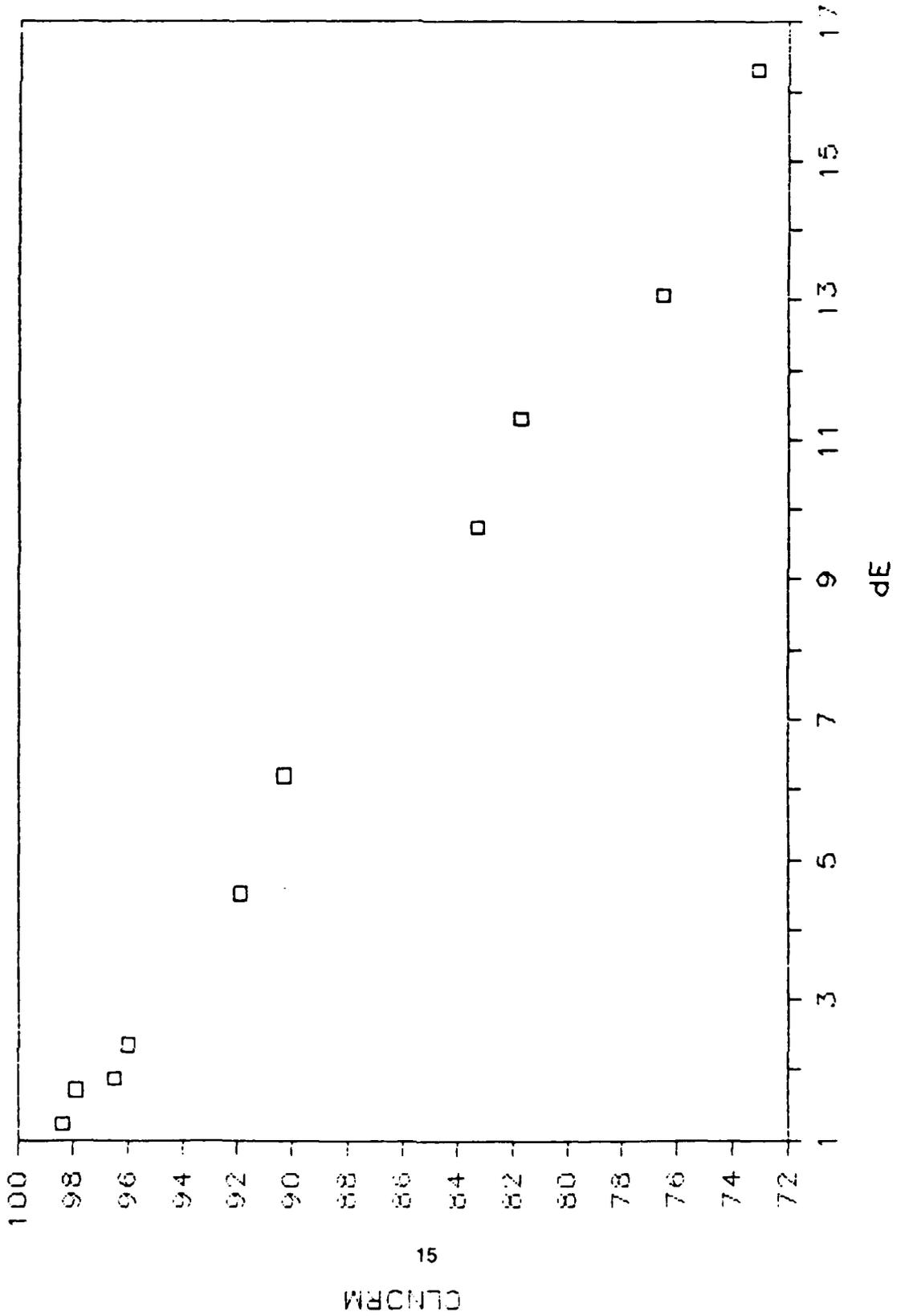


Figure 5 Clnorm Versus dE of Original Topcoats

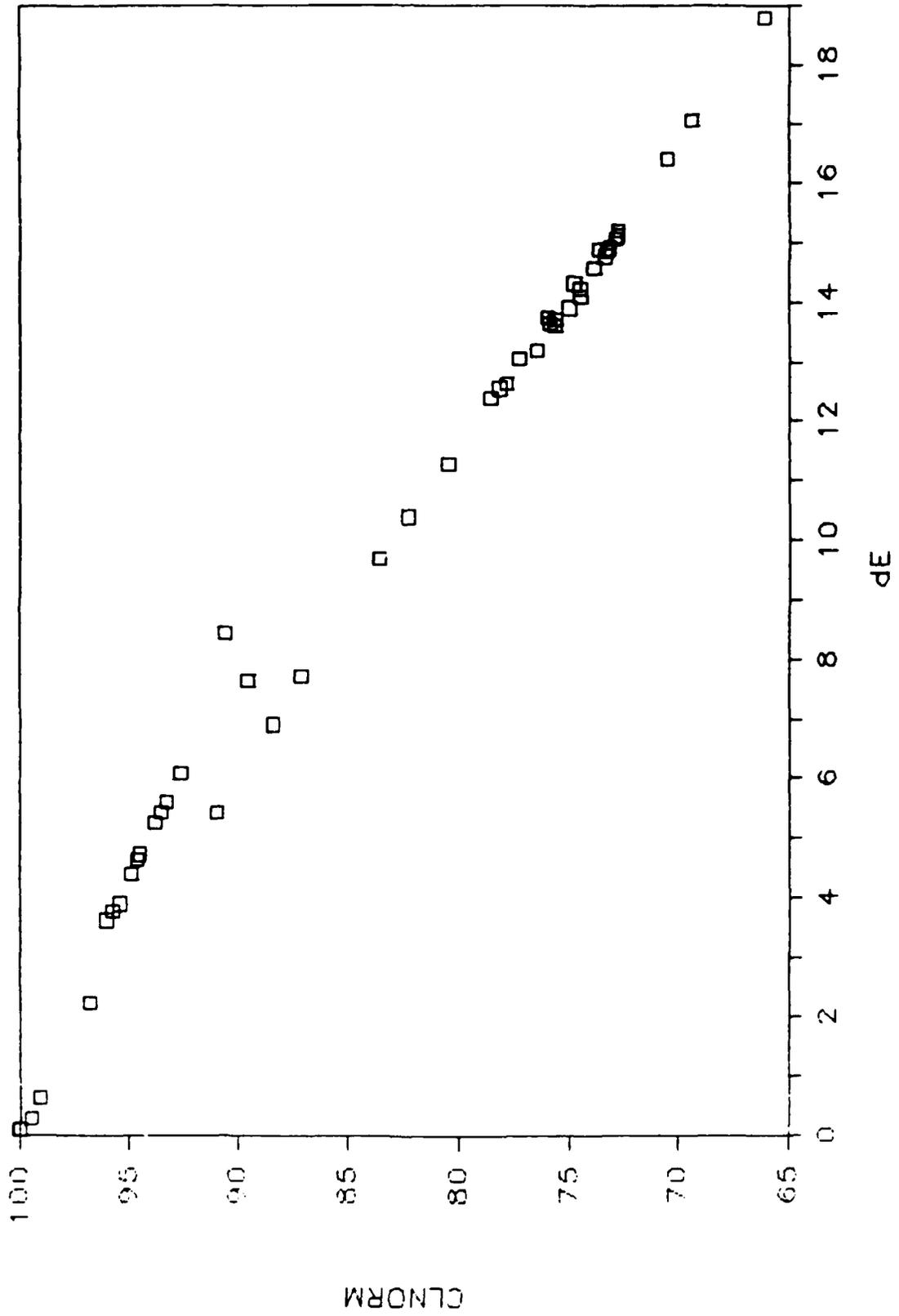


Figure 6 Clnorm Versus dE for Polyurethane Topcoats

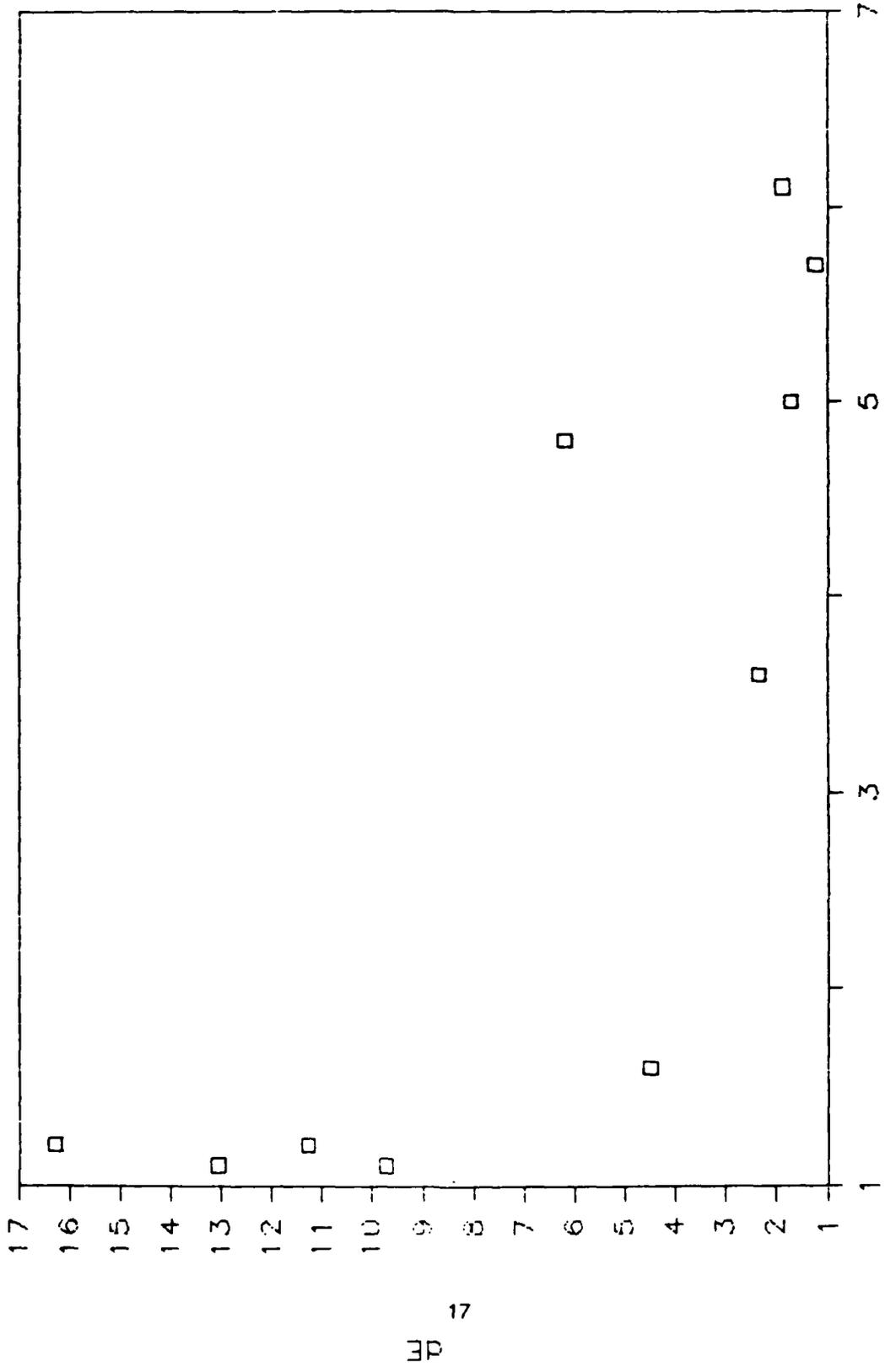


Figure 7 dE Versus Gloss for Original Topcoats

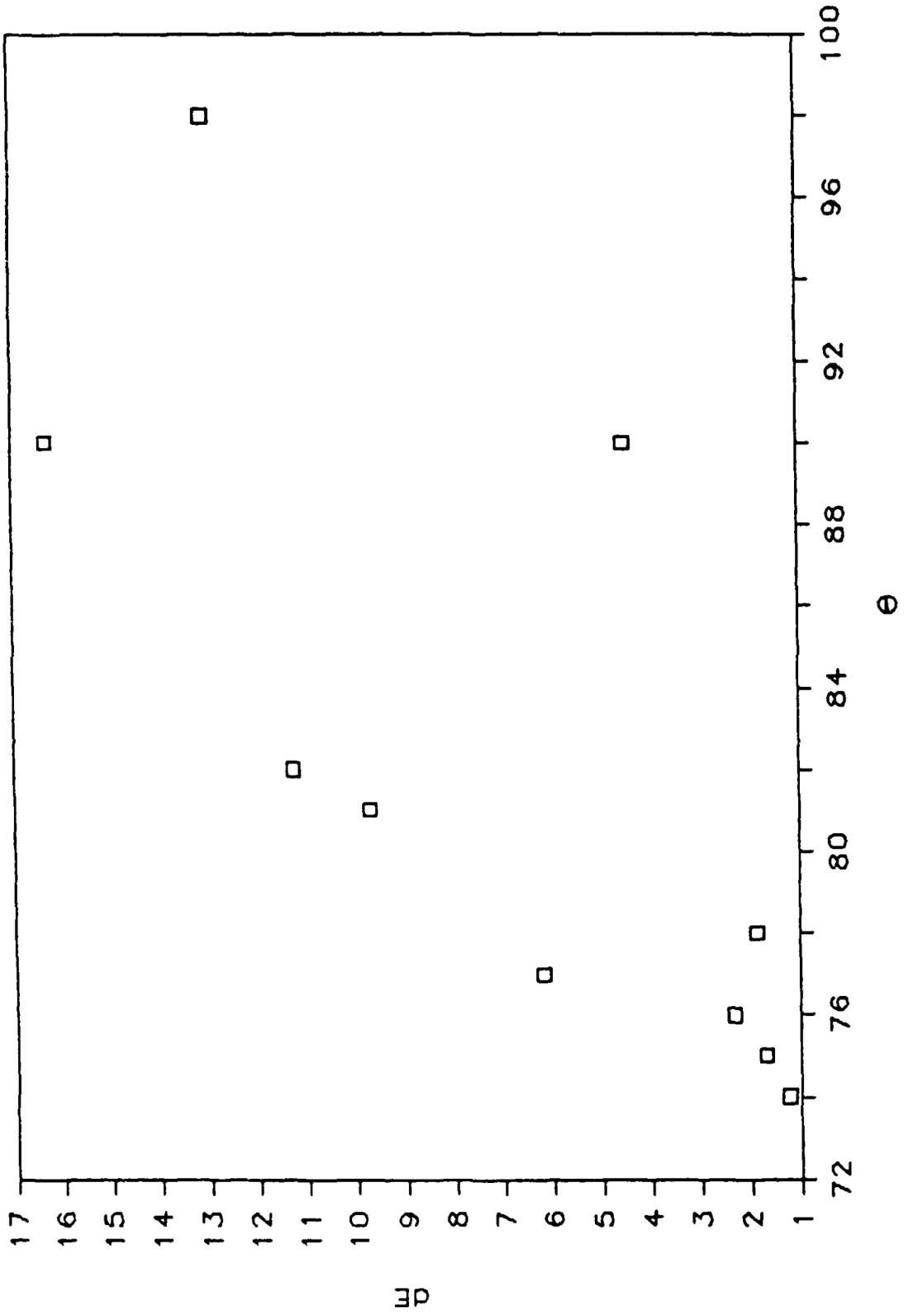


Figure 8 dE Versus Contact Angle for Original Topcoats

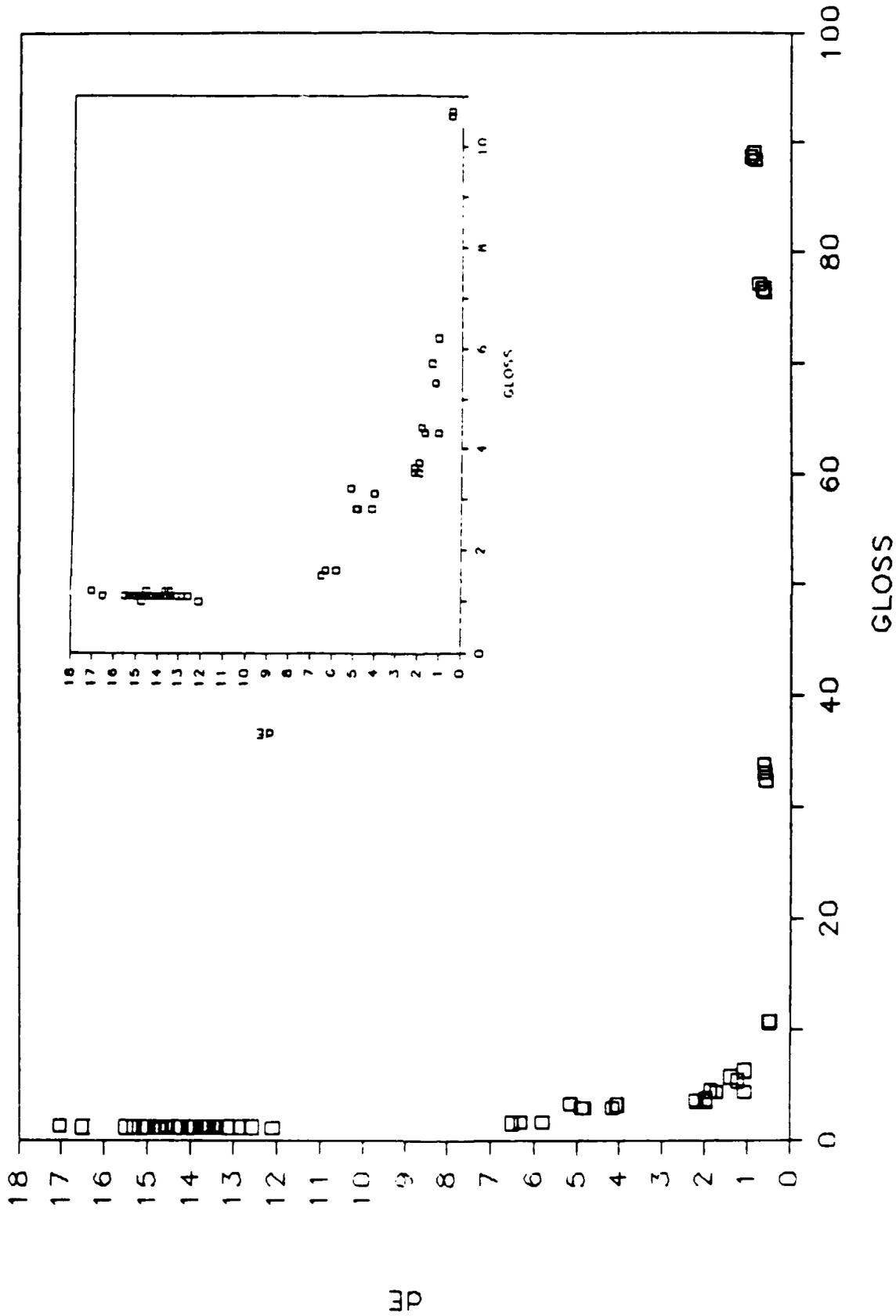
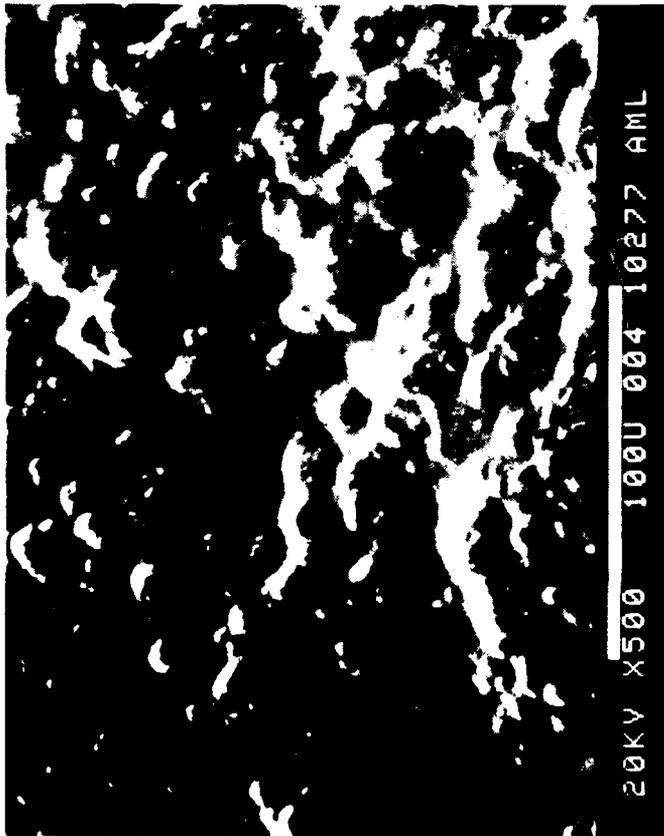
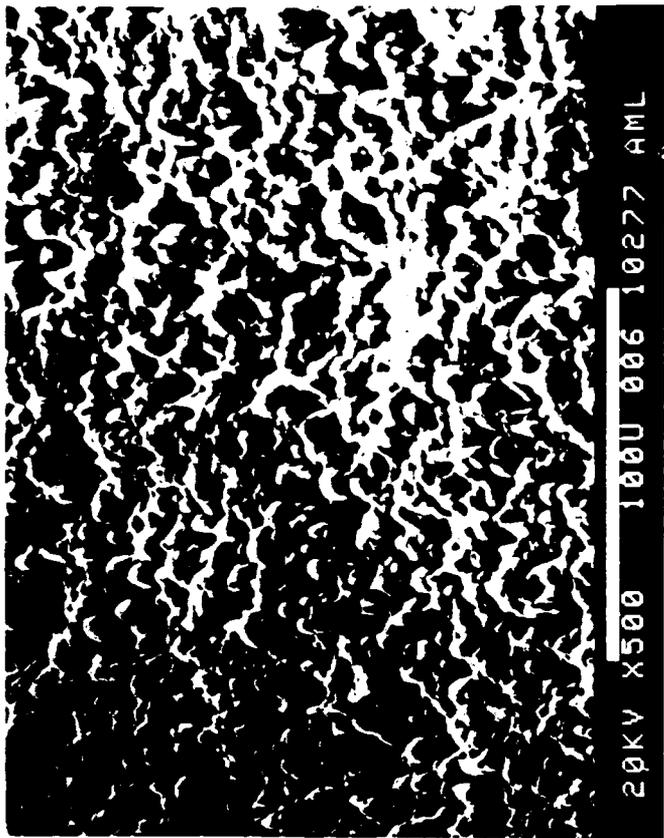


Figure 9 dE Versus Gloss for Polyurethane Topcoats

# TOPOGRAPHY OF POLYURETHANE TOPCOATS - SEM

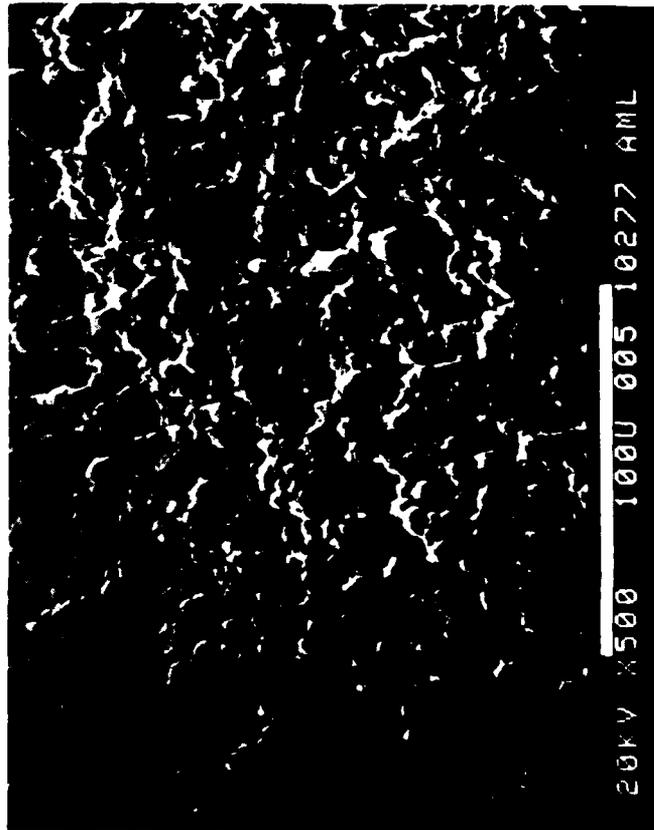


A



C

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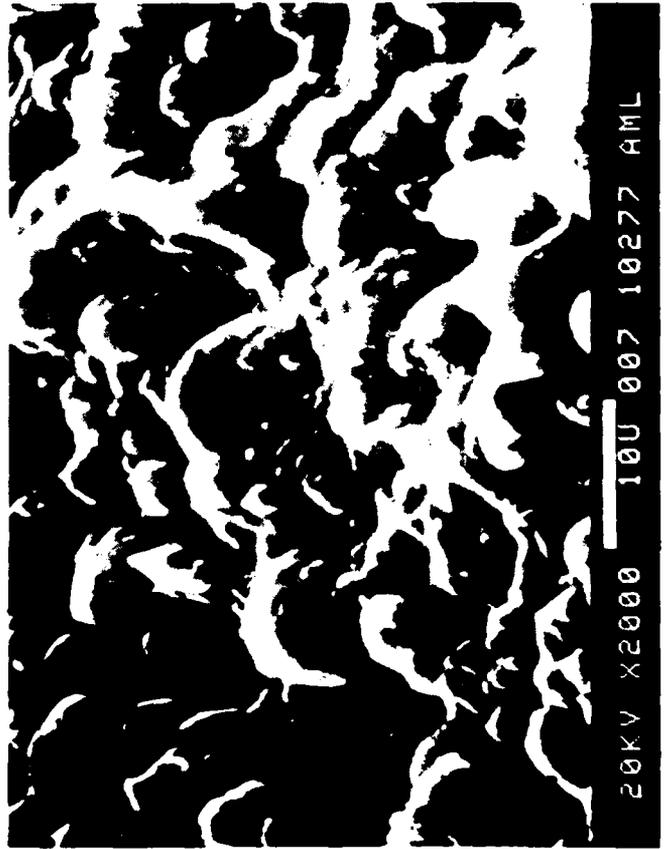


B

- A: DEFT, 36320
- B: DESOTO, 36320
- C: CAMOLITE, 36320

Figure 10 Scanning Electron Micrographs of Polyurethane Topcoats, 500X

TOPOGRAPHY OF POLYURETHANE TOPCOATS - SEM



A: DEFT, 36320

B: DESOTO, 36320

C: CAMOLITE, 36320

NADC 87164-60

Figure 11 Scanning Electron Micrographs of Polyurethane Topcoats, 2000X

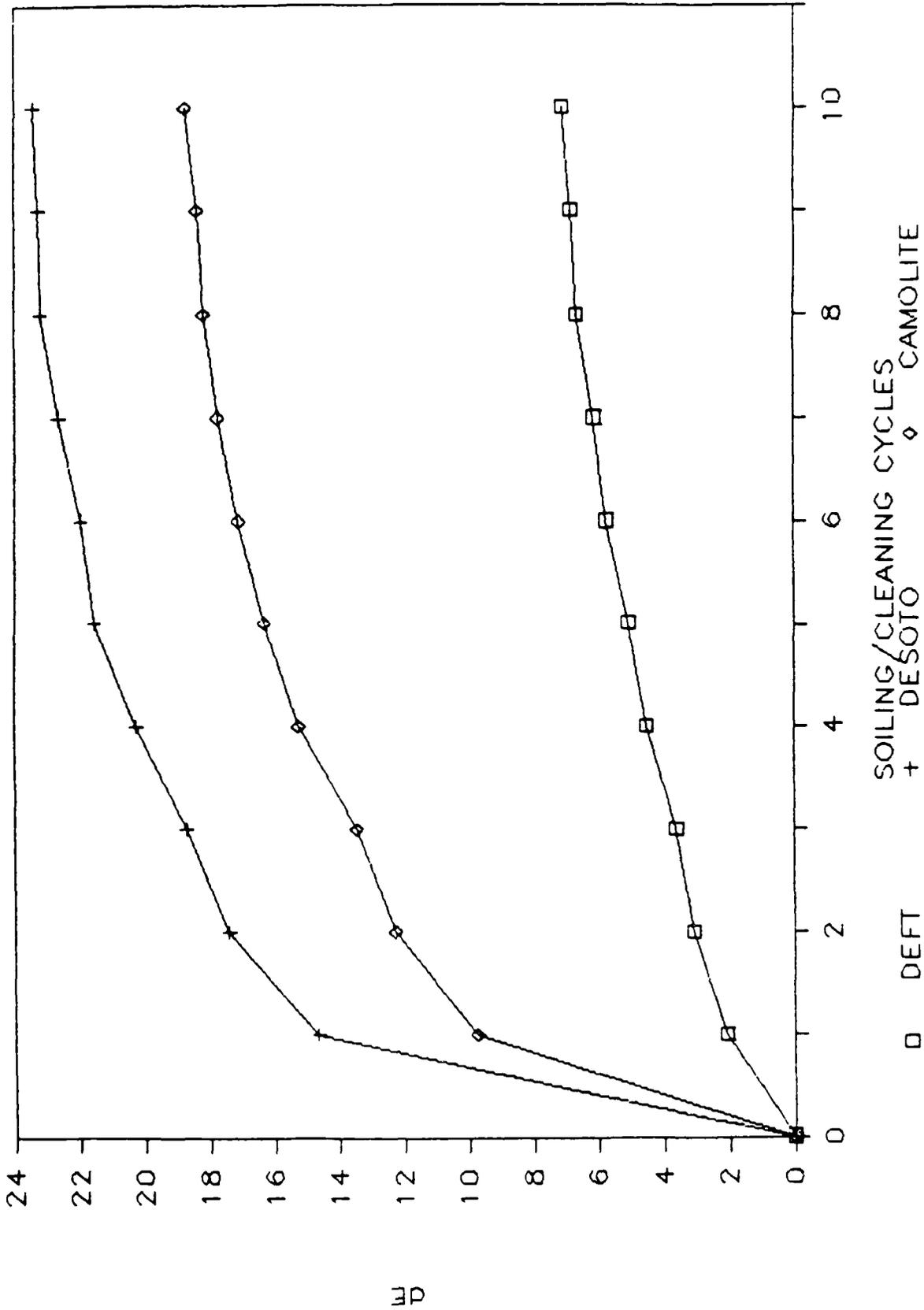


Figure 12 dE Versus Soiling/Cleaning Cycles for Polyurethane Topcoats

## APPENDIX A: COMPOSITION OF NADC SELF-PRIMING TOPCOAT

<u>COMPONENT A</u>	<u>PERCENT BY WEIGHT</u>
Polyester Polyol Resin Solution (1)	37.8
Titanium Dioxide (2)	1.1
Titanium Dioxide Vesiculated Beads (3)	0.4
Zinc Phosphate (4)	17.1
Organo-Zinc Salt (5)	1.7
Zinc Molybdate (6)	30.1
Carbon Black (7)	trace

COMPONENT B

Hexamethylene Diisocyanate Resin Solution (1) 11.8

These materials are mixed approximately 4 parts of Component A to 1 part of Component B, by volume.

- (1) Coatings for Industry, Inc., Souderton, PA (Urethabond X3009 A and B)
- (2) E. I. DuPont DeNemours and Company, Wilmington, DE (Ti-Pure R-960)
- (3) Enterprise Chemicals, Chicago, IL (Spindrifit 20929)
- (4) Mineral Pigments Corp., Beltsville, MD (Phos-Plus J0866)
- (5) BASF, Holland, MI (Sicorin RZ)
- (6) Sherwin-Williams, Chicago, IL (Moly-White 101)

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### APPENDIX B: CLEANABILITY TEST FOR AIRCRAFT COATINGS

This method is a laboratory procedure for determining the cleanability of an aircraft coating. It is a modification of a proposed ASTM method for evaluating the cleaning efficiency of aircraft exterior surface cleaners which is described in detail in reference (6). The soil listed in the procedure below was generated using a hydraulic fluid. This soil is representative of that found on fleet operational aircraft as discussed in references (7) and (8). Other soils can be derived from greases and lubricating oils.

#### 1.0 Apparatus

1.1 Test panels 3 x 6 x 0.02 inches (7.62 x 15.24 x 0.05 cm), cut from 2024 T3 aluminum alloy chromate conversion coated with materials conforming to MIL-C-81706 to produce a coating meeting MIL-C-5541.

1.2 One-quart (1 L), wide mouth, glass glass jars

1.3 Balance, accurate to 0.1 g

1.4 High shear mixer

1.5 Hog bristle brush (Gardner WG-2000-B)

1.6 Acid brushes

1.7 Rubber roller, 5.0 ± 0.1 pounds (2270 ± 50 grams)

1.8 Forced draft oven capable of 221°F ± 4 (105°C ± 2).

1.9 Wear tester (Gardner Heavy Duty Wear Tester)

1.10 Template for positioning panels on the wear tester (See Figure A-1)

1.11 Cellulose sponge backed with nylon web (Scotch Brite 63).

#### 2.0 Preparation of Soil

2.1 Place 50.0 ± 0.5 grams of carbon black (such as Raven 1040 manufactured by Columbian Chemical Company) and 500 ± 1 gram of MIL-H-83282 hydraulic fluid.

2.2 Homogenize the mixture from 2.1 using a high shear mixer for 15 ± 1 minute. Prior to application of the soil to the test specimen, thoroughly stir or shake the mixture.

#### 3.0 Preparation of the Control Formula Cleaner

3.1 The following is a control formula for MIL-C-85570, Type II aircraft cleaner as listed in paragraph 4.6.13.1 of the specification.

3.2 Mix the first five ingredients listed below, then neutralize the mixture to a pH of 8.0 with acetic acid. Mix the last two ingredients together and then add that to the initial mixture.

## NADC 87164-60

Igepal CO-630 (1)	10.0 grams
Monamid 150 CW (2)	5.0
Dipropylene glycol methyl ether	10.0
Deionized water	71.5
Benzotiazole	0.5
Hostacor 2098 (3)	2.0
Morphaline	1.0

- (1) GAF Corporation or equivalent
- (2) Mona INdustries, Inc. or equivalent
- (3) American Hoechst Corp. or equivalent

### 4.0 Preparation of Test Panels

4.1 To the aluminum test specimens described in 1.1, apply MIL-P-23377 epoxy primer to a thickness of 0.6 to 0.9 mils (15.2 to 22.9  $\mu$ m). Allow to dry for 1 hour at ambient laboratory conditions. Apply the desired topcoat to the intended thickness. For MIL-C-83286 polyurethane, mix the two components and allow a 30 minute dwell time. Apply MIL-C-83286 to a thickness from 1.8 to 2.2 mils (45.7 to 55.9  $\mu$ m). Allow the coating to cure under the appropriate conditions, 2 weeks at ambient laboratory conditions for MIL-C-83286.

4.2 After allowing the desired cure time and conditions, use a bristle acid brush to coat the painted surface of a test panel with the soil described in 2.0. Remove excess soil by covering the test panel surface with absorbent tissue and exerting pressure by rolling the tissue with the 5 pound roller. Repeat this blotting three times using fresh tissue each time. Brush the soiled surface 10 times in one direction only, parallel to the long dimension of the test panel, using the hog bristle brush. Bake the test panel at  $221^{\circ}\text{f} \pm 4$  ( $105^{\circ}\text{C} \pm 2$ ) for  $60 \pm 1$  minute.

4.3 Measure the L, a, and b tristimulus values on a suitable colorimeter and record the values as  $L_i$ ,  $a_i$ , and  $b_i$ , respectively.

### 5.0 Cleaning Procedure

5.1 Dilute the control cleaner by 1 part cleaner with 9 parts distilled water (by volume).

5.2 Clean the test panel within 4 hours using the wear tester as follows. Cut the sponge with any texture "ribs" running perpendicular to the cleaning stroke and the dimension parallel to the cleaning stroke is 3.5 inches (90 mm) and the width is 2.75 inches (70 mm). When the dry sponge is attached to the cleaning head of the wear tester, the combined weight shall be between 1350 and 1400 grams. (Note: Use Velcro type strips on the cleaning head to attach the nylon web side of the sponge). Place soiled test panel in the template at  $45^{\circ}$  to the cleaning stroke (see Figure A-1). Saturate the sponge and cover the test panel with the diluted cleaner. After 55 to 65 seconds, clean the test panel using 5 cycles (10 strokes) of the wear tester, then immediately turn the test panel  $90^{\circ}$  in the template and clean for an additional 5 cycles. Rinse the test panel under a flowing stream of tap water at room temperature and allow to fully dry. Perform at least 3

NADC 87164-60

replicates for each coating.

5.3 Measure the L, a, and b values on the same colorimeter used in 4.3 and record them as  $L_f$ ,  $a_f$ , and  $b_f$ , respectively.

5.4 Calculate the change in color due to soiling and cleaning according to:

$$dE = \sqrt{(L_f - L_i)^2 + (a_f - a_i)^2 + (b_f - b_i)^2}$$

5.5 A minimum of 3 replicates were tested for each coating at each condition.

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4.3 Measure the L, a, and b tristimulus values on a suitable colorimeter and record the values as L<sub>1</sub>, a<sub>1</sub>, and b<sub>1</sub>, respectively.

#### 5.0 Cleaning Procedure

5.1 Dilute the control cleaner by 1 part cleaner with 9 parts distilled water (by volume).

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5.5 A minimum of 3 replicates were tested for each coating at each condition.

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