REPORT NO. PE-67-4

COPY NO.:____

CONFIDENTIAL DU PONT TECHNICAL INFORMATION

E. I. DU PONT DE NEMOURS & COMPANY, INC.
FABRICS & FINISHES DEPARTMENT
PRODUCTION DIVISION
DIVISIONAL PROCESS ENGINEERING GROUP
COLOR OPERATIONS SECTION

A STUDY OF SHADING PROCEDURES FOR SATURATED COLORS

By: S. W. Rementer

Date Issued: October 10, 1967

Project: P-57, General Technical Support

ABSTRACT

An investigation of saturated colors is undertaken to supply more practical shading corrections by taking advantage of less stringent color tolerances for saturated color space.

A STUDY OF SHADING PROCEDURES FOR SATURATED COLORS

TABLE OF CONTENTS

INTRODUCTION

Visual color shading depends on a man's ability to distinguish color differences, and his shading experience to correctly discern the colorants needed for an acceptable color match. Since the eye is the final arbitrator of all color matching, instrumental color definition should parallel visual definition as closely as possible. Recent and continuing studies describing the instrumental measurement of visually accepted color matches indicate that visual tolerances, though tight and nearly symmetrical about the standard for products of moderate saturation, become less strict as saturation increases. Visual tolerance zones become elongated in the saturation direction and offset from the standard center point.

Saturated colors pose special problems to instrumental shading that were not presented to the visual shader. Computerized vector shading attempts to provide a numerically perfect color match in all regions of color space. This need not be accomplished for a good visual match of saturated colors, and production efficiency is cut when it is attempted. Unrealistically large additions of colorant are often necessary to achieve instrumental color agreement when a fraction of this amount is needed for visual agreement.

This study was initiated to present possible methods of assimilating visual appraisal into instrumental shading of saturated colors.

RESULTS

1. A 780-line yellow and a 780-line red were successfully shaded by manual calculations involving only lightness and hue from on-load positions significantly more saturated than the product standard. The colorant additions (hits) calculated this way reduced the amount of colorant needed for shading to quantities closely approximating visual experience. Proper on-load positioning is important for the successful operation of this method. Conventional vectors should be used when the batch is not sufficiently saturated with respect to standard. The hits made in this manner are termed two-dimensional or planar hits.

2. Readings were encountered for which no solutions were obtainable because no combination of colorant gave the needed prescribed movement.

3. No successful shading technique that would decrease hit size was found for saturated oranges.

4. Hits calculated by analog computer could be reduced in size by removing colorants with high shading concentrations that provided vector movement approximated by another colorant from the shading scheme. Under these circumstances the analog computer gave hits very similar to those calculated manually, if the vector card were modified to show only the lightness and hue effects of the remaining colorants.

5. The planar hits without redundant colorants did not always provide better hits than with these colorants since maneuverability (the vector scheme's ability to provide shading corrections for any on-load position) was sometimes hampered greatly.

CONCLUSIONS

1. Specific planar functions numerically describing color differences by incorporating only lightness and hue may be used in specialized cases to more closely approximate visually prescribed hits for saturated yellows and reds. This method will not shade saturated oranges to visually acceptable positions.

2. Many large hits may be reduced by removing redundant colorants from the shading scheme.

3. Each problem product must be examined independently to ascertain if either or both of the above methods will aid in providing Production with useable hits.

4. The job of shading may be made easier by formulation that considers the needs of instrumental shading. Providing balanced colorants giving nearly equalateral vector movement and formulation that takes into account the offset tolerances of saturated colors may help.

RECOMMENDATIONS

1. Continued study of visual-instrumental tolerance correlations.

2. Problem products be studied to find and remove any high concentration colorants that give redundant vector displacement. Care must be exercised so that maneuverability is not greatly reduced.

3. Emergency degenerate vectors may then be established, if necessary, to handle cases requiring further consideration of the hit size.

PREPARED BY: S. W. Rementer
S. W. REMENTER

APPROVED BY: R. H. Vining
R. H. VINING

DISCUSSION

The Modified Adams Color Coordinate System describes a point in color space by the set of orthogonal axes; lightness (L), Red-Green (a), and Yellow-Blue (b). Matching a color standard is accomplished by constructing a like coordinate system about the product standard. Each colorant in the product is described by a vector (ΔL, Δa, Δb) anchored at the origin.

At the present time, instrumental shading by vector movement simultaneously controls each axis equally until the batch is within a nearly cubical tolerance range centered on the product standard. This can be described as shading to minimize the function $E = (\Delta L^2 + \Delta a^2 + \Delta b^2)^{1/2}$. Studies of saturated yellows, oranges, and red indicate that it is not necessary to control all coordinates within the same tolerances for a good visual match.

Saturated yellows must be controlled for lightness (ΔL) and Red-Green hue (Δa), but have a wide (Δb) tolerance as illustrated by the passing delta values of the following. Greater positive (Δb) variation, or increased saturation, can be tolerated visually than can negative (Δb) variation, or desaturation.

Yellow

Product Code	ΔL	Δa	Δb
A780-1226	+0.05	+0.16	+3.60
0-780-75306	-0.05	-0.22	+0.89
	+0.03	-0.11	+0.46
116-1346	+0.16	-0.06	+0.79
247-3404	+0.12	-0.19	-1.20
253-52422	-0.24	-0.22	+0.83
Y-797-78068	+0.12	+0.16	-0.47
	+0.35	-0.10	-1.07
**81-26545	+0.15	-0.38	+3.38
	+0.50	-0.34	+3.62
	+0.32	-0.56	+5.37
**83-26841	-0.17	+0.34	+1.14

The visual tolerance range, though nearly cubical for products of moderate saturation, becomes elongated perpendicular to the lightness-hue plane as specified saturation increases.

* Du Pont Registered Trademark

**Data by G. C. Cline, S.S.F., "Zone Charts for Yellow, Orange and Red 'Dulux*'", letter to W. H. Edwards, February 8, 1965.

Saturated Reds follow much the same pattern as the Yellows. Reds need to be controlled more for lightness (ΔL) and Yellow-Blue hue (Δb), than for (Δa). Again, it is more difficult to perceive too much Red (increased saturation) than too little Red (desaturation) in a saturated Red. The following passing panels indicate the lesser importance of controlling (Δa) compared to (ΔL) and (Δb).

Red

Product Code	ΔL	Δa	Δb
A780-59758	-0.02	+2.17	+1.61
	-0.02	+1.46	+0.18
868-99130	-0.12	+0.68	-0.03
868-98138	-0.22	+0.54	+0.37
93-24118	-0.06	+1.16	+0.30
	-0.28	+2.16	+0.62
93-24440	-0.56	+0.11	-0.38
	-0.61	+2.80	+0.37
	-0.88	+1.86	+0.07
	-0.72	+2.34	+0.14
	-0.12	+1.45	+0.80
	-0.56	+1.24	+0.07

There is greater restriction on lightness variations than either (Δa) or (Δb) for oranges. The tolerance zone may be elongated parallel to a line passing through the absolute origin of color space and the point in color space marking the product standard.

Orange

Product Code	ΔL	Δa	Δb
243-92029	+0.30	+0.51	+0.58
A780-082	-0.18	+0.70	+1.29
83-19045	0.00	+0.62	+0.78
	+0.10	+1.10	+0.48

Modified Instrumental Shading Techniques

Saturated Reds and Yellows often require unrealistically large additions of colorant, and the corresponding amount of resin, to achieve an acceptable instrumental color match by minimizing E. A significant decrease in the amount of colorant necessary for shading can be had by taking advantage of the less stringent visual tolerance zones of the saturated region of color space. Specific planar functions will permit shading to a visually acceptable point providing the on-load delta values insure against visually perceptible desaturation at negligible hue variation.

The planar function for saturated Yellows deletes the (Δb) effect and shades by minimizing $(\Delta L^2 + \Delta a^2)^{1/2}$. Comparisons to conventional shading for A780-1226 indicate the effectiveness of this method for different on-load positions.

I. On-Load $\Delta L = +1.53$
$\Delta a = +2.15$
$\Delta b = +4.09$

Conventional Hit		$(\Delta L^2 + \Delta a^2)^{1/2}$	
24.0%	42-687	0.79%	743-123
0.12%	42-622	0.03%	42-224
0.016%	42-224		
24.14%	Total	0.82%	Total
		3.4%	of conventional hit

Computed Outcome (C.O.)	C.O.
$\Delta L =$ 000	$\Delta L = +0.01$
$\Delta a =$ 000	$\Delta a =$ .000
$\Delta b = +0.06$	$\Delta b = +0.86$

II. On-Load $\Delta L = +0.42$
$\Delta a = +0.49$
$\Delta b = +1.52$

Conventional Hit		$(\Delta L^2 + \Delta a^2)^{1/2}$	
15.2%	42-687	0.009%	42-224
0.11%	42-622		
15.31%	Total		
		0.06%	of conventional hit

C.O.	C.O.
$\Delta L = +0.24$	$\Delta L = -0.02$
$\Delta a = -0.10$	$\Delta a = -0.02$
$\Delta b = -0.36$	$\Delta b = +0.86$

III. On-Load

$\Delta L = +0.42$
$\Delta a = -0.49$
$\Delta b = +1.52$

Conventional Hit

0.28%	743-123
3.90%	42-687
0.09%	42-622
4.27%	Total

C.O.

$\Delta L = -0.01$
$\Delta a = +0.02$
$\Delta b = +0.03$

$(\Delta L^2 + \Delta a^2)^{1/2}$

0.06%	42-622
0.002%	42-224
0.062%	Total

1.5% of conventional hit

C.O.

$\Delta L = +0.02$
$\Delta a = +0.01$
$\Delta b = +0.82$

IV. On-Load

$\Delta L = -0.42$
$\Delta a = +0.49$
$\Delta b = +1.52$

Conventional Hit

1.56%	743-123
1.2%	42-687
0.01%	42-622
2.77%	Total

C.O.

$\Delta L = 0.01$
$\Delta a = .000$
$\Delta b = +0.05$

$(\Delta L^2 + \Delta a^2)^{1/2}$

1.54%	743-123

55.6% of conventional hit

C.O.

$\Delta L = +0.02$
$\Delta a = +0.01$
$\Delta b = +0.26$

V. On-Load

$\Delta L = -0.42$
$\Delta a = -0.49$
$\Delta b = +1.52$

Conventional Hit	
2.42%	743-123
5.95%	42-686
0.10%	42-622
8.47%	Total

$(\Delta L^2 + \Delta a^2)^{1/2}$	
8.00%	42-686
.04%	42-622
8.04%	Total

94.9% of conventional hit

C.O.

$\Delta L = -0.01$
$\Delta a = +0.07$
$\Delta b = +0.03$

C.O.

$\Delta L = -0.03$
$\Delta a = -0.03$
$\Delta b = +2.36$

VI. On-Load

$\Delta L = +1.92$
$\Delta a = +3.62$
$\Delta b = +4.30$

Conventional Hit	
11.4%	42-687
0.05%	42-224
11.45%	Total

$(\Delta L^2 + \Delta a^2)^{1/2}$	
2.68%	743-123
0.05%	42-224
2.73%	Total

23.8% of conventional hit

C.O.

$\Delta L =$ 000
$\Delta a =$ 000
$\Delta b = +0.10$

C.O.

$\Delta L = -0.01$
$\Delta a = +0.09$
$\Delta b = -1.41$

VII. On-Load

$\Delta L = +1.20$
$\Delta a = +1.69$
$\Delta b = +2.94$

Conventional Hit	
1.04%	42-687
0.05%	42-622
0.02%	42-224
10.47%	Total

$(\Delta L^2 + \Delta a^2)^{1/2}$	
0.65%	743-123
0.028%	42-224
0.68%	Total

6.5% of conventional hit

C.O.

$\Delta L = +0.02$
$\Delta a = +0.01$
$\Delta b = +0.10$

C.O.

$\Delta L =$ 000
$\Delta a = -0.02$
$\Delta b = +0.36$

VIII. On-Load

$\Delta L = -0.57$
$\Delta a = +0.96$
$\Delta b = +0.04$

Conventional Hit

0.44%	743-123
3.3%	42-686
9.7%	42-687
13.44%	Total

$(\Delta L^2 + \Delta a^2)^{1/2}$

3.44%	42-686
0.03%	42-224
3.47%	Total

25.9% of conventional hit

C.O.

$\Delta L = -0.15$
$\Delta a = 000$
$\Delta b = +0.01$

C.O.

$\Delta L = +0.04$
$\Delta a = +0.01$
$\Delta b = -2.23$

IX. On-Load

$\Delta L = -0.53$
$\Delta a = -0.10$
$\Delta b = -0.09$

Conventional Hit

1.1%	743-123
6.5%	42-686
0.06%	42-622
7.66%	Total

$(\Delta L^2 + \Delta a^2)^{1/2}$

7.72%	42-686

100.8% of conventional hit

C.O.

$\Delta L = -0.14$
$\Delta a = -0.08$
$\Delta b = +0.02$

C.O.

$\Delta L = -0.11$
$\Delta a = 000$
$\Delta b = +1.01$

In all tests but IX the hit size was reduced at least slightly. Test VI and VIII predict end points that may be too desaturated to be acceptable.

The following datum shows how closely the hit minimizing $(\Delta L^2 + \Delta a^2)^{1/2}$ matches the visually prescribed hit for Y797-78068, Yellow with on-load figures.

$\Delta L = +0.80$
$\Delta a = +1.29$
$\Delta b = -0.24$

Conventional Computer Hit

5.3%	42-686
0.17%	42-622
0.019%	42-224
5.49%	Total

C.O.

$\Delta L = +0.44$
$\Delta a = +0.39$
$\Delta b = +0.09$

$(\Delta L^2 + \Delta a^2)^{1/2}$ Hit

0.015%	42-224

0.27% of conventional hit

C.O.

$\Delta L = -0.01$
$\Delta a = +0.01$
$\Delta b = -1.52$

Visually Prescribed Hit

0.01%	42-224

Actual End Point

$\Delta L = +0.12$
$\Delta a = +0.16$
$\Delta b = -0.47$

giving an acceptable visual match.

The planar function for the Red portion of the color solid would be $(\Delta L^2 + \Delta b^2)^{1/2}$. Again the batch should be loaded sufficiently Red to standard to insure against visually perceptible desaturation at the end point. The following tests for A780-59758, Red, indicate the effectiveness of this formula for varying starting points.

I. On-Load

$\Delta L = +0.73$
$\Delta a = +4.24$
$\Delta b = +2.81$

Conventional Hit

2.76%	743-655
0.36%	743-123
0.07%	42-224
3.19%	Total

C.O.

$\Delta L = -0.07$
$\Delta a = +0.09$
$\Delta b = -0.05$

$(\Delta L^2 + \Delta b^2)^{1/2}$

0.38%	743-123
0.06%	42-224
0.44%	Total

13.8% of conventional hit

C.O.

$\Delta L = +0.03$
$\Delta a = +0.91$
$\Delta b = -0.02$

II. On-Load

$\Delta L = -0.64$
$\Delta a = +0.54$
$\Delta b = -0.14$

Conventional Hit		$(\Delta L^2 + \Delta b^2)^{1/2}$	
3.6%	743-655	1.55%	743-655
0.25%	743-123	0.25%	743-123
0.02%	42-224		
3.87%	Total	1.80%	Total

46.5% of conventional hit

C.O.	C.O.
$\Delta L = -0.04$	$\Delta L = -0.07$
$\Delta a = +0.05$	$\Delta a = +0.61$
$\Delta b = -0.02$	$\Delta b = -0.10$

III. On-Load

$\Delta L = -0.19$
$\Delta a = -0.07$
$\Delta b = +0.49$

Conventional Hit		$(\Delta L^2 + \Delta b^2)^{1/2}$	
0.20%	743-123	0.21%	743-123

105.0% of conventional hit

C.O.	C.O.
$\Delta L = -0.01$	$\Delta L = +0.07$
$\Delta a = -0.40$	$\Delta a = -0.30$
$\Delta b = +0.18$	$\Delta b = +0.02$

IV. On-Load

$\Delta L = -0.43$
$\Delta a = +0.65$
$\Delta b = +0.35$

Conventional Hit		$(\Delta L^2 + \Delta b^2)^{1/2}$	
1.71%	743-655	0.57%	743-655
0.20%	743-123	0.19%	743-123
0.01%	42-224		
1.92%	Total	0.76%	Total

39.6% of conventional hit

C.O.	C.O.
$\Delta L = -0.01$	$\Delta L = +0.03$
$\Delta a = +0.01$	$\Delta a = +0.54$
$\Delta b = $ 000	$\Delta b = +0.07$

V. On-Load $\Delta L = +0.54$
$\Delta a = -0.40$
$\Delta b = -0.34$

Conventional Hit		$(\Delta L^2 + \Delta b^2)^{1/2}$	
2.95%	743-655	3.04%	743-655
3.60%	743-300	4.07%	743-300
6.55%	Total	7.11%	Total
		108.5% of conventional hit	

C.O.	C.O.
$\Delta L = +0.01$	$\Delta L = 000$
$\Delta a = -0.07$	$\Delta a = -0.16$
$\Delta b = +0.02$	$\Delta b = +0.05$

VI. On-Load $\Delta L = +0.75$
$\Delta a = +1.51$
$\Delta b = -0.65$

Conventional Hit		$(\Delta L^2 + \Delta b^2)^{1/2}$	
6.35%	743-655	4.26%	743-655
2.40%	743-300	5.40%	743-300
0.04%	42-224		
		9.66%	Total
8.79%	Total		
		109.9% of conventional hit	

C.O.	C.O.
$\Delta L = +0.01$	$\Delta L = +0.09$
$\Delta a = +0.01$	$\Delta a = +2.02$
$\Delta b = -0.01$	$\Delta b = -0.02$

Batches of this material that are light and blue to standard present a problem as there is no vector movement out of that quadrant.

The planar functions are useful only in the sections of color space near the +a or +b axes, where one absolute coordinate is larger than the other. They are of no use for shading orange where a and b are more or less equal.

In most instances, saturated products are shade variations of a single pigment, or two similar pigments. Similar pigments require high concentrations for relatively small vector movements when letdown in each other. Saturated yellows may be mostly W-686 and/or W-687. Oranges may be mostly W-622, and reds mostly W-655 and/or W-300. For example, 42-687, used in A780-1226, requires a concentration of 24.9% for a vector movement of 2.53 N.B.S. units. 743-123, also used in this product, moves into the same octant, (+,-,-), as 42-687 and requires a concentration of only 1.72%. The largest movement of 42-687 ($\Delta a = 2.12$) can be duplicated by 743-123 with a 40% saving of material. There is no great loss in maneuverability since the product has four remaining component colorants. The following points were calculated by computer for A780-1226 without using 42-687 for shading purposes. The percentage of the conventional hit (previously given) follows each calculation.

I. On-Load

$\Delta L = +1.53$
$\Delta a = +2.15$
$\Delta b = +4.09$

Hit		Computed Outcome
1.4%	743-123	$\Delta L = +0.02$
0.025%	42-622	$\Delta a = +0.03$
0.03%	42-224	$\Delta b = +0.16$
1.43%	Total	

5.9% of conventional hit

II. On-Load

$\Delta L = +0.42$
$\Delta a = +0.49$
$\Delta b = +1.52$

Hit		C.O.
0.78%	743-123	$\Delta L =$ 000
0.02%	42-622	$\Delta a =$ 000
0.009%	42-224	$\Delta b = +0.04$
0.81%	Total	

5.3% of conventional hit

III. On-Load

$\Delta L = -0.42$
$\Delta a = +0.49$
$\Delta b = +1.52$

Hit		C.O.
1.58%	743-123	$\Delta L = +0.08$
		$\Delta a = -0.05$
		$\Delta b = +0.09$

57.0% of conventional hit

IV. On-Load

$\Delta L = +0.42$
$\Delta a = -0.49$
$\Delta b = +1.52$

Hit		C.O.
0.73%	743-123	$\Delta L = +0.03$
0.02%	42-622	$\Delta a = +0.04$
0.002%	42-224	$\Delta b = +0.04$
0.75%	Total	

18% of conventional hit

V. On-Load

$\Delta L = -0.42$
$\Delta a = -0.49$
$\Delta b = +1.52$

Hit		C.O.
1.78%	743-123	$\Delta L = -0.01$
43%	42-686	$\Delta a = -0.01$
0.06%	42-622	$\Delta b = -0.07$

72.4% of conventional hit

VI. On-Load $\Delta L = +1.92$
$\Delta a = +3.63$
$\Delta b = +4.30$

Hit		C.O.
0.03%	42-224	$\Delta L = -0.11$ $\Delta a = +0.40$ $\Delta b = -0.06$

0.76% of conventional hit

VII. On-Load $\Delta L = -0.57$
$\Delta a = +0.96$
$\Delta b = +0.04$

Hit		C.O.
1.0%	743-123	$\Delta L = -0.05$
9.1%	42-686	$\Delta a = +0.19$
0.01%	42-224	$\Delta b = -0.02$

75.2% of conventional hit

VIII. On-Load $\Delta L = -0.53$
$\Delta a = -0.10$
$\Delta b = -0.09$

Hit		C.O.
0.32%	743-123	$\Delta L = -0.28$
2.5%	42-686	$\Delta a = -0.15$
		$\Delta b = +0.06$
2.82%	Total	

36.8% of conventional hit

All hits were improved by at least 25% of the conventional hit. This is not a planar method and does not require proper on-load positioning for use.

Once the extraneous 42-687 is removed from the vector card the computer is capable of assimilating the planar method. Only the lightness and hue components are recorded on the shading card. It will again be necessary to have correct on-load positioning for effective use.

Examples

I. On-Load $\Delta L = +1.53$
$\Delta a = +2.15$
$\Delta b = +4.09$

Hit		C.O.
0.72%	743-123	$\Delta L = +0.04$
0.02%	42-224	$\Delta a =$ 000
		$\Delta b = +0.86$
0.74%	Total	

II. On-Load $\Delta L = +0.42$
$\Delta a = +0.49$
$\Delta b = +1.52$

Hit		C.O.
0.007%	42-224	$\Delta L = +0.04$ $\Delta a = +0.04$ $\Delta b = +0.93$

III. On-Load $\Delta L = +1.92$
$\Delta a = +3.63$
$\Delta b = +4.30$

Hit		C.O.
1.82%	743-123	$\Delta L = -0.05$
0.8%	42-686	$\Delta a = -0.02$
0.03%	42-224	$\Delta b = -1.36$
2.65%	Total	

IV. On-Load $\Delta L = +1.20$
$\Delta a = +1.69$
$\Delta b = +2.94$

Hit		C.O.
0.4%	743-123	$\Delta L = -0.02$
0.02%	42-224	$\Delta a =$ 000
		$\Delta b = +0.42$

If 42-687 were not removed, tests I and II would not change. Tests III and IV, however, would change to:

III. Hit		C.O.
13.2%	42-687	$\Delta L = +0.05$
0.02%	42-224	$\Delta a = +0.04$
		$\Delta b = +0.35$
13.22%	Total	

IV. Hit		C.O.
2.5%	42-687	$\Delta L = +0.05$
0.02%	42-224	$\Delta a = +0.04$
		$\Delta b = +0.87$
2.52%	Total	

Conventional hits for A-780-59758 can be improved by removing 743-300 from shading use. 743-300 moves to the same octant as 42-224 and has 275 times the concentration of 42-224. Maneuverability is hampered in this case, as only three vectors remain for shading. Tests I, IV and V were not satisfactorily shaded.

I. On-Load $\Delta L = +0.73$
$\Delta a = +4.24$
$\Delta b = +2.81$

	Hit		C.O.
	0.28%	743-123	ΔL = +0.40
	0.06%	42-224	Δa = -0.65
			Δb = +0.32
	0.34%	Total	
			10.7% of conventional hit

II.	On-Load		ΔL = -0.64 Δa = +0.54 Δb = -0.14
	Hit		C.O.
	1.9%	743-655	ΔL = -0.08
	0.22%	743-123	Δa = +0.15
	0.01%	42-224	Δb = -0.07
	2.13%	Total	
			55% of conventional hit

III.	On-Load		ΔL = -0.19 Δa = -0.07 Δb = +0.49
	Hit		C.O.
	0.11%	743-123	ΔL = -0.02 Δa = -0.23 Δb = +0.16
			55% of conventional hit

IV.	On-Load		ΔL = +0.54 Δa = -0.40 Δb = -0.34
	Hit		C.O.
	0.19%	743-655	ΔL = +0.58 Δa = -0.34 Δb = -0.23
			2.9% of conventional hit

V.	On-Load		ΔL = -0.43 Δa = -0.65 Δb = +0.35
	Hit		C.O.
	.06%	743-123	ΔL = -0.32 Δa = -0.74 Δb = +0.17
			11% of conventional hit

VI. On-Load

$\Delta L = -0.43$
$\Delta a = +0.65$
$\Delta b = +0.35$

Hit		C.O.
1.71%	743-655	$\Delta L =$ 000
0.21%	743-123	$\Delta a = +0.01$
0.01%	42-224	$\Delta b =$ 000
1.92%	Total	100% of conventional hit

The majority of tests calculating planar solutions by computer gave better solutions when 743-300 was included in the shading scheme. Planar solutions excluding 743-300 closely followed the manually computed solutions. Only in the first test did removing 743-300 improve the hit.

I. On-Load

$\Delta L = +0.73$
$\Delta a = +4.24$
$\Delta b = 2.81$

A with 743-300		C.O.
611%	743-300	$\Delta L = -0.02$
0.94%	743-123	$\Delta a = +2.13$
		$\Delta b = +0.04$
7.04%	Total	
		220.7% of conventional hit

B w/o 743-300		C.O.
0.28%	743-123	$\Delta L =$ 000
0.05%	42-224	$\Delta a = +0.89$
		$\Delta b =$ 000
0.33%	Total	
		10.3% of conventional hit

II. On-Load

$\Delta L = +1.14$
$\Delta a = +2.03$
$\Delta b = +0.79$

A with 743-300		C.O.
0.81%	743-655	$\Delta L =$ 000
2.81%	743-300	$\Delta a = +1.57$
		$\Delta b =$ 000
3.62%	Total	
		104.9% of conventional hit

R w/o 743-300		C.O.
5.02%	743-655	$\Delta L = +0.08$
0.07%	42-224	$\Delta b = -1.55$
		$\Delta b = -0.11$
5.09%	Total	
		146.4% of conventional hit

III. On-Load

$\Delta L = +0.54$
$\Delta a = -0.40$
$\Delta b = -0.34$

<u>A with 743-300</u>

2.17%	743-655
2.43%	743-300
4.60%	Total

<u>C.O.</u>

$\Delta L = +0.01$
$\Delta a = -0.06$
$\Delta b = -0.01$

70.2% of conventional hit

<u>B w/o 743-300</u>

6.76%	743-655
.06%	42-224
6.82%	Total

<u>C.O.</u>

$\Delta L = +0.06$
$\Delta a = -2.98$
$\Delta b = -0.03$

104.4% of conventional hit

IV. On-Load

$\Delta L = +0.86$
$\Delta a = -0.32$
$\Delta b = +1.01$

<u>A with 743-300</u>

2.84%	743-300
0.03%	743-123
2.87	Total

<u>C.O.</u>

$\Delta L =$ 000
$\Delta a = -0.50$
$\Delta b =$ 000

90.25% of conventional hit

<u>B w/o 743-300</u>

3.72%	743-655
0.06%	42-224
3.78%	Total

<u>C.O.</u>

$\Delta L = -0.11$
$\Delta a = -3.37$
$\Delta b = +0.07$

118.9% of conventional hit

These tests make it evident that, although the modifications may help to shade certain problem products, no set method for all saturated colors is forthcoming. It seems that 42-687 can be removed from shading consideration for A-780-1226 with no harmful effects. Maneuverability is not restricted, and a useable planar function is obtained. A-780-59758 does not lend itself as readily to the preceding methods. Removing 743-300 restricts shading from some positions to an undesirable degree. Hit size is increased as often as it is decreased by using planar methods. Only in certain cases will vector card modifications achieve the desired objective. Each problem product will have to be investigated to determine if these methods, either singularly or in combination, will aid in providing more useable hits.

A correlation may be formed between the absolute color coordinates A and B and the visual tolerance region for a given product. Weights for (Δa) and (Δb) can be calculated as a function of saturation and the perpendicular color coordinate. The factor Wa for (Δa) would be -

$$W_a = \frac{(K_a\ B^2}{(S^2} + \frac{C)}{S)} = \frac{(K_a\ B^2}{(A^2 + B^2)} + \frac{C}{(A^2 + B^2)^{1/2}}$$

such that

1. K_a is an experimentally determined constant giving the ratio of W_a + u Wl (the lightness factor). If, for example (ΔL), (Δa) and (Δb) must be equally controlled for an orange with A = B, then W_a = 1.0. Neglecting C/S, K_a would equal 2.0.

$$W_a = \frac{2\ B^2}{S^2} = \frac{2\ B^2}{2\ B^2} = 1.0$$

If (Δa) and (Δb) tolerances were twice the (ΔL) tolerance for this orange K_a (and K_b) equals one.

$$W_a = \frac{B^2}{S^2} = 0.5$$

2. C is an experimentally determined constant to increase the weight as saturation decreases causing the tolerances to equalize.

As W_x (x = a,b) goes to zero, the necessity of close control for axis x decreases.

The weights show a pattern for A-780-1226, A-780-59758 and 0-780-98166, a saturated orange, that follows the tolerances presented earlier in this discussion.

1. Let W_L = 1.0
2. $K_a = K_b$ = 1.0
3. C = 0

a. A-780-1226

A = 0.14B

$$W_a = \frac{B^2}{(0.14B)^2 + B^2} = 0.98$$

$$W_b = \frac{(0.14B)^2}{(0.14B)^2 + B^2} = 0.02$$

b. A-780-59758

A = 1.91B

$$W_a = \frac{B^2}{(1.91B)^2} + B^2 = 0.22$$

$$W_b = \frac{(1.91B)2}{(1.91B)2} + B2 = 0.79$$

c. A-780-98166

A = 0.9B

$$W_a = \frac{B^2}{(.9B)^2} + B^2 = 0.55$$

$$W_b = \frac{(.9B)^2}{(.9B)^2} + B^2 = 0.45$$

These weights do not account for the offset of visual acceptance toward increased saturation. They do help to reunite the yellow, orange and red portions of color space, partitioned by considering the planar shading solutions which are applicable only in regions near the absolute color axes.

DISTRIBUTION LIST

		COPY NO.
C. F. KALB F. H. BEADLES	- WILM. F. & F.) IN - " ") TURN	1
K. E. ACKLEY	- SO. SAN FRAN.	2
F. S. BAKER	- TUCKER	3
W. H. BEUTEL	- PHILADELPHIA	4
R. A. DE WALL	- CHICAGO	5
J. F. MC GETTIGAN	- PARLIN	6
P. O. PEASLEY	- EVERETT	7
C. W. STAHL	- TOLEDO	8
H. R. STINE	- FLINT	9
C. H. THOMPSON	- FORT MADISON	10
W. H. EDWARDS	- PHILADELPHIA	11
R. H. VINING	- PHILADELPHIA	12
PROCESS ENGINEERING FILE COPIES		13-20