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E. I. DU PONT DE NEMOURS & COMPANY
FABRICS & FINISHES DEPARTMENT
PRODUCTION DIVISION
PHILADELPHIA PROCESS ENGINEERING

E-1

APPEARANCE CHARACTERIZATION & CONTROL OF STRIP-COATING FINISHES - PART II

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PE 61-01

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ABSTRACT

Problems inherent in color measurements of flat and semi-gloss products are discussed and instrumental methods permitting such measurements are detailed.

P-60 APPEARANCE CHARACTERIZATION AND CONTROL OF STRIP-COATING FINISHES

Part II - Application and Alignment of Colormaster for Reflectance Measurements of Flat and Semi-Gloss Finishes

Introduction

Part I of this report has reviewed the basic conditions that must prevail if color is to be shaded and controlled instrumentally. If these prerequisites are recognized and accepted, then many of the problems hindering the successful application of instrumentation will be eliminated. In the interval, formulations not adhering to the basic concepts, particularly with respect to pigmentation, can be successfully handled, but only by individuals capable of exercising a high degree of judgement. The belief that the instrumental approach to color results in a mechanical system is highly erroneous, judgement is an integral part of the work.

Experience has shown that panels measured at gloss levels equal to standard, have not posed problems but color measurements of two panels at different gloss levels have been a problem. Part II of this report covers the problems inherent in color measurement and control of flat and semi-gloss products versus standards of different gloss levels. The weakness of all tri-stimulus colorimeters where surface irregularities of the finishes being measured can result in light scattering, hence partial measurement of specular gloss along with light emerging from the pigmented film, have been recognized and guarded against in the past through the design of the instruments themselves. In the measurement of flat and semi-gloss products one is faced with, by the very nature of the products, color measurements on irregular surfaces where controlled scattering of specular gloss is an integral property of the product.

It has long been accepted that color adjustments and batch turnover time on flat and semi-gloss products are much greater on these products than on high gloss products. The eye has difficulty in distinguishing between color differences that are solely functions of gloss and real differences indicating hue variations, hence the need for instrumentation. The tri-stimulus colorimeter, properly standardized and used by skilled personnel can accurately measure color differences on these products. By analysis, the operator can then determine what portion of the measured color difference is due solely to gloss variations, and what portion is a result of hue variations.

Techniques permitting accurate and reproducible reading using the Colormaster on flat and semi-gloss products are examined.

Results

It is apparent from the work completed to date that gloss variations of equal magnitude have an increasingly greater effect as the reflectance of the color decreases; i.e., dark colors are more greatly affected by gloss variations than are light colors. In all colors a reduction in gloss results in an apparent increase in the lightness of the color. This reflectance change is a result of the scattering of the gloss component of light reflected from the film because of the irregularity of the film surface caused by the flattening agent. Previous work has shown that this gloss component has essentially the same color composition as the light striking the film.

In neutral grays, the essentially equal G, R and B reflectance values are approximately equally affected by the gloss component, hence the effect of gloss variations is primarily in the lightness direction with little or no effect on the hue or saturation of the color (note Exhibit A).

In saturated colors, the unequal G, R and B reflectance values are not evenly affected by the gloss component resulting in a three-fold effect, in that instrumentally a pronounced change (loss) in saturation as well as in hue occurs, plus the increase in lightness previously noted for neutral grays (note Exhibit B). Visually the eye accepts these colors as being equal to their respective standards and does not detect the hue and saturation changes measured instrumentally. The eye does detect minor variations in lightness levels in the dark colors, but these are not considered to be objectionable based on visual inspection by trained color personnel.

During the course of this investigation it was noted that different Colormasters varied in their ability to measure panels of different gloss levels relative to a standard. This fact was confirmed by a "round robin" test on panels of varying gloss increments prepared at Process Engineering and divisionally read. The data showing the variation between Colormasters within the Division have been compiled and distributed by E. A. Miller. These data are included as Exhibit C in this report.

<u>Conclusions</u>

1) Techniques that permit accurate and reproducible reflectance measurements on flat and semi-gloss panels have been developed and are detailed in this report.

2) Lack of visual and instrumental correlation between panels differing in gloss can now be explained, since it has been established that tri-stimulus colorimeters detect color differences not discernible by the eye. This condition exists in non-metameric matches.

3) Alignment of Divisional "Colormasters" to make meaningful Division color tolerances can be readily established using techniques detailed in this report.

<u>Discussion</u>

The results of this investigation indicate that the response of the "Colormaster" Differential Colorimeter to gloss variations differs with each unit. These differences are believed to be caused by very minor variations with respect to positioning of the optical system and photo tubes in each instrument. Other tri-stimulus instruments would show the same variations. In addition to the variation noted between clean units, it is possible to obtain considerable variation within an instrument because of variations in the cleanliness of the filters, optics, mirrors and gloss plates above the photo tubes. This is not surprising since the presence of grime and dust particles will tend to disperse the light in much the same way as the flattening component of a film does. This will produce an additive effect when coupled to film gloss of a panel.

In order to remain instrumentally consistent on a given Colormaster it is essential that each instrument be rigorously cleaned prior to initial use and that daily cleaning of the glass plate over the photo tube and the mirror using a camel hair brush be strictly enforced. Dust particles accumulating on these surfaces can result in major measurement errors due to their ability to scatter light. To assist further it is essential that each plant site number their individual colorimeters, and all readings pertaining to a batch be made on the same colorimeter. Cleaning of all optics following P.T.S.P. #18, page 9, section F-2, should be established on a cycle based on conditions existing at each location.

The following procedure is recommended for obtaining instrumental color readings on batches which are to be instrumentally controlled, where gloss differences exist between the batch and standard due to the use of a high gloss color standard.

1) Select an approved batch that is visually considered to be FULLY equal to the dry plate standard.

2) Calibrate the dry plate standard on a properly cleaned Colormaster versus the white ceramic plaque using semi-absolute colorimetry. Assign these values to the dry plate standard.

   For example -

   Values determined for dry plate standard versus white ceramic plaque.

   G = 78.10
   R = 79.60
   B = 79.02

3) Read the visually approved and accepted batch panel versus the calibrated dry plate standard. Record G, R and B values for the batch along with the Plant colorimeter number.

4) Repeat on each additional Colormaster, first standardizing the Colormaster using the G, R and B values for the dry plate standard (determined in point 2). Read the selected batch versus the dry plate standard, recording G, R and B values along with the instrument number. Designate values as G_n, R_n and B_n. Values of visually accepted batch

(point 1) versus dry plate standard.

	D.P.S.	#1 Colormaster	#2 Colormaster	#3 Colormaster
G =	78.10	G_1 = 78.41	G_2 = 78.90	G_3 = 79.50
R =	79.60	R_1 = 80.50	R_2 = 79.00	R_3 = 79.40
B =	79.02	B_1 = 74.10	B_2 = 76.10	B_3 = 76.14

To control production batches, using a clean and properly serviced Colormaster, the following procedure should be used:

5) Standardize the Colormaster to the values determined for the dry plate standard in step 2.

6) Determine G, R and B values for the production batch versus the dry plate standard using semi-absolute colorimetry. Production batch versus D.P.S. read on Colormaster #3:

D.P.S.	Batch
G = 78.10	G = 73.96
R = 79.60	R = 73.86
B = 79.02	B = 68.84

7) Calculate delta values using for standard values, those values determined in step 3, not the values shown for the calibration of the dry plate standard. Care must be taken to select those values assigned for the particular Colormaster used. An example of the calculation involved is as follows:

Determination of ΔL, Δa, Δb values for Colormaster 3.

Standard	Batch
G_3 = 79.50	G = 73.96
R_3 = 79.40	R = 73.86
B_3 = 76.14	B = 68.84

ΔL = -2.40
Δa = -1.04
Δb = +1.52

A summary of the steps involved are shown below:

(A) Values determined for dry plate standard versus white ceramic plaque - G = 78.10
R = 79.60
B = 79.02

(B) Values of visually accepted batch (point 1) versus dry plate standard -

D.P.S.	#1 Colormaster	#2 Colormaster	#3 Colormaster
G = 78.10	G_1 78.41	G_2 78.90	G_3 79.50
R = 79.60	R_1 80.50	R_2 79.00	R_3 79.40
B = 79.02	B_1 74.10	B_2 76.10	B_3 76.14

(C) Production batch versus D.P.S. standard read on Colormaster 3:

D.P.S.	Batch
G = 78.10	G 73.96
R = 79.60	R 73.86
B = 79.02	B 68.84

(D) Determination of ΔL, Δa, Δb for Colormaster 3:

Standard	Batch
G_3 = 79.50	G 73.96
R_3 = 79.40	R 73.86
B_3 = 76.14	B 68.84

$$\Delta L = -2.40$$
$$\Delta a = -1.04$$
$$\Delta b = +1.52$$

Divisional Alignment of Colormasters

When two or more locations are manufacturing the same product code and close alignment is mandatory, it is essential that the Colormasters at each site be aligned with respect to the product. This is critical where gloss differences exist between product and approval standards. If alignment is not made, then passing tolerances with respect to a standard can be farcical because of varying sensitivity of each unit where gloss is a factor in measurements. Alignment of Colormasters from plant to plant is relatively simple and straightforward. This can be accomplished as follows:

1) The "parent" plant must send to each manufacturing site a panel of the visually approved batch, along with a dry plate standard, assuming this standard is not already available.

2) Upon receipt of these panels, the plant should standardize the Colormaster to the values shown on the dry plate standard. The visually approved batch panel should then be read against the dry plate standard and the values for G, R and B duly recorded along with the instrument number.

These values are then used for calculation purposes, as shown in the preceding example. The passing batch panel should then be returned to the parent plant; or alternately, if a calibrated dry plate standard is available at the plant then only the approved batch panel need be forwarded. Upon receipt of this panel, the panel should be carefully read versus the dry plate standard via semi-absolute colorimetry and G, R and B values duly recorded showing the instrument number the values apply to. These values should then be used for calculation purposes. The approved batch panel should then be returned to the parent plant.

EXHIBIT A

Neutral Gray

% Flatting Pigment	0%	1%	1.5%	2%	3%	3.5%	4%	5%
Lightness ≒ 85								
Gloss	86.0	43.5	30.50	22.80	12.50	6.30	5.30	4.30
G	67.90	67.95	67.96	68.30	69.02	66.98	70.19	70.12
R	68.55	68.61	68.60	68.92	69.66	70.72	71.03	70.80
B	66.20	66.28	66.40	66.62	67.28	67.68	67.91	68.06
ΔL		+ .01	+0.03	+ .20	+ .56	+1.03	+1.13	+1.10
Δa		- .03	0.00	- .08	- .07	- .14	+ .02	- .15
Δb		+ .05	- .14	- .04	+ .01	+ .45	+ .42	+ .24
Lightness ≒ 50								
Gloss	85.50	46.50	34.50	23.70	9.80	8.10	5.50	2.60
G	21.16	21.32	21.44	21.52	22.71	23.18	23.91	24.78
R	21.54	21.73	21.83	21.88	23.03	23.52	24.24	25.11
B	20.64	20.80	20.93	21.04	22.31	22.84	23.56	24.45
ΔL		+0.16	+ .28	+0.36	+1.60	+2.06	+2.78	+3.60
Δa		+0.12	+0.11	+0.02	-0.17	+0.02	-0.12	-0.17
Δb		+0.00	-0.02	-0.10	-0.22	- .35	-0.33	-0.38
Lightness ≒ 15								
Gloss	87.0	45.00	36.00	21.30	10.40	8.00	5.30	2.90
G	2.755	3.012	3.078	3.534	4.985	5.130	5.857	6.720
R	2.697	2.964	3.026	3.468	4.858	5.012	5.700	6.550
B	2.939	3.220	3.290	3.760	5.244	5.391	6.124	6.942
ΔL		+ .84	+1.08	+2.46	7.57	+7.97	+9.85	+11.88
Δa		+ .46	+ .39	+0.54	-.23	- .18	- .35	- .50
Δb		- .18	- .18	-0.32	+.10	+ .12	+ .18	+ .50

NOTE:

Gloss readings were made at 60° and are reported to show order of magnitude of gloss change resulting from addition of flatting pigment. It is recognized that certain readings are outside the normal 60° limits, but are presented to avoid complexities resulting from scale changes.

EXHIBIT B

885-0557 - Lightness ≈ 85

% Flatting Pigment		0%	1%	1.5%	2.0%	3.0%	3.5%	4.0%	5.0%
G	=	70.44	70.24	70.29	70.45	70.88	71.07	71.19	71.82
R	=	62.10	61.88	61.93	62.10	62.44	62.63	62.72	63.27
B	=	87.28	87.20	87.25	87.41	87.94	88.03	88.30	88.90
ΔL			- .10	- .08	0.00	+ .22	+ .32	+ .36	+ .67
Δa			- .02	+ .01	+ .02	- .02	- .10	- .04	- .16
Δb			- .11	- .11	- .08	- .09	+ .01	- .15	0.00

L ≈ 50

G	20.66	20.92	21.13	21.69	22.31	22.68	22.92	23.53
R	10.49	10.81	11.08	11.70	12.36	12.76	13.01	13.66
B	57.78	57.92	58.10	58.53	59.10	59.41	59.63	60.13
ΔL		+ .28	+ .56	+1.10	+1.74	+2.12	+2.37	+2.98
Δa		+ .39	+ .62	+ .69	+ .92	+ .95	+ .96	+1.03
Δb		+ .31	+ .52	+1.12	+1.66	+2.01	+2.21	+2.77

L ≈ 15

G	2.490	2.713	2.918	3.139	3.732	4.042	4.378	5.228
R	.940	1.185	1.397	1.610	2.206	2.457	2.831	3.696
B	15.22	15.23	15.43	15.71	16.36	16.63	17.13	18.09
ΔL		+ .99	+1.88	+2.74	+4.90	+5.94	+6.98	+9.42
Δa		-1.39	-2.16	-2.92	-4.69	-6.12	-6.18	-7.50
Δb		+1.65	+2.64	+3.53	+5.57	+6.99	+7.68	+9.78

EXHIBIT B (Cont'd)

885-0362 - Lightness ⊥ 85

% Flatting Base		1%	1.5%	2%	3%	3.5%	4%	5%
G =	72.01	71.95	71.96	71.92	72.28	72.41	73.68	73.68
R =	79.27	79.26	79.31	79.37	79.63	79.83	81.11	81.20
B =	65.94	65.84	65.82	65.73	66.16	66.26	67.48	67.44
ΔL		- .02	- .02	- .04	+ .13	+ .20	+ .81	+ .81
Δa		00	+1.12	+2.24	+2.10	+2.18	+2.02	+2.15
Δb		+ .05	+ .11	+ .13	+ .03	+ .05	+ .05	+ .09

L ⊥ 50

G	20.14	20.17	20.27	20.48	21.04	21.19	21.70	21.89
R	31.12	31.13	31.26	31.44	31.98	32.16	32.66	32.83
B	11.15	11.22	11.34	11.68	12.31	12.49	13.09	13.42
ΔL		+ .04	+ .15	+ .38	+ .98	+1.14	+1.68	+1.88
Δa		- .06	- .03	- .22	- .56	- .55	- .89	- .97
Δb		- .14	- .27	- .77	-1.10	-1.59	-2.14	-2.61*

(*) Visually appears sl. blue

L ⊥ 30

G	74.89*	74.99*	75.70*	76.29*	78.06*	79.01*	80.20*	86.96*
R	15.02	15.01	15.10	15.16	15.38	15.43	15.58	16.25
B	9.89*	10.59*	11.06*	11.93*	13.61*	15.50*	16.54*	24.88*

(*) 10X multiplier

ΔL		+ .03	+ .17	+ .30	+ .73	+ .85	+1.09	+2.41
Δa		+ .03	- .06	- .15	- .35	-1.67	-1.78	-2.07
Δb		- .83	-1.20	-2.08	-3.42	-5.17	-5.85*	-10.99**

(*) Visually appears slightly bluer than standard
(**) Bluer than standard, but not to extent shown instrumentally

EXHIBIT B (Cont'd)

885-0630 - Lightness ± 85

% Flatting Pigment			1%	1.5%	2%	3%	3.5%	4%	5%
G	=	71.45	71.37	71.38	71.54	72.09	72.67	72.53	73.11
R	=	80.18	80.09	80.12	80.29	80.78	81.20	81.12	81.33
B	=	43.50	43.49	43.48	43.66	44.59	45.32	45.08	45.66
ΔL			- .04	- .04	+ .04	+ .32	+ .60	+ .54	+ .81
Δa			+ .05	+ .07	+ .03	+ .08	- .15	- .02	- .60
Δb			- .05	- .04	- .07	- .70	-1.04	- .90	-1.08

L ± 55

G	=	25.14	25.08	25.04	25.19	25.52	25.74	26.08	26.67
R	=	35.17	35.02	34.99	35.12	35.42	35.60	35.92	36.52
B	=	31.35*	31.65*	32.47*	34.76*	39.32*	42.01*	46.83*	54.63*
ΔL			- .06	- .10	+ .05	+ .36	+ .57	+ .89	+1.44
Δa			- .17	- .05	- .09	- .06	- .31	- .37	- .40
Δb			- .36	- .90	-2.10	-4.19	-5.30	-7.19	-9.83

(*) 10X multiplier

EXHIBIT C

CC: O. R. VOLK - MARSHALL LAB.
J. C. DOHERTY - PHILA.

Philadelphia Plant
September 25, 1961

W. H. EDWARDS

PROCESS ENGINEERING
MEMO

AN INVESTIGATION OF MEASURING TWO PANELS OF THE SAME COLOR BUT DIFFERENT GLOSS LEVELS ON THREE COLORMASTERS

A previous study indicated non-reproducible results between three colormasters when measuring two panels of the same color but different gloss levels - one a high gloss and one a flat. This study was extended to cover all of the colormasters on the Philadelphia Plant to determine degree of variance that might be expected in the division.

Location of Colormaster	Panel G-85 Gloss	Panel G-85 + 6% Syloid Flat	ΔG
Sales Development	67.60	69.93	2.33
Plt. I.C.A.	67.60	69.55	1.95
Process Eng.	67.60	69.87	2.27
Process Eng. Lab.	67.60	69.92	2.32
Control Lab.	67.60	70.14	2.54
B Group	67.60	70.10	2.50

A similar check will be made of the colormasters in the division. Panels to be air-mailed to the plants September 22, 1961.

The flat panel was oiled and then read on the Sales Development and Plant I.C.A. colormasters.

	Reading	Gloss G-85	Flat G-85	
I.C.A.	1	67.60	66.91	
	2	67.60	66.94	
	3	67.60	66.89	
	4	67.60	66.82	
Sales Develop.	1	67.60	66.80	
	2	67.60	66.94	
	3	67.60	66.90	
	4	67.60	66.87	
P.E.	1	67.60	68.14	(VZ-1204)

DUP030002258

The oil film thickness does affect the G reading but the ropiness of the oil film seems to have some effect. It was found the most reproducible results were obtained by oiling the panel freely then wiping off with a dry cloth.

It was recommended to O. Volk that some means be developed to raise the gloss of the flat panels and new values be established, in order to avoid the variance between colormasters due to gloss.

PROCESS ENGINEERING

E. A. Miller

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EXHIBIT C

CC: O. R. VOLK - MARSHALL LAB.
W. H. TOOLE - " "

Philadelphia Plant
October 16, 1961.

W. H. EDWARDS

COLORIMETER-CHART COLOR ADJUSTMENT SYSTEM (P-57)
USE OF SEMI-GLOSS STANDARDS FOR CONTROL OF FLAT PANELS
DIVISIONAL

When we were unable to reproduce the ΔG value of a gloss and a flat panel using two colormasters in the Philadelphia Plant, a survey was made to include all colormasters in the division. The following data show the ΔG difference as measured on colormasters in the plants and the same panels measured in Process Engineering:

	P.E.				P.E. minus plant ΔG values
ΔG	1.80	1.30	Chicago		+ 0.50
"	1.42	1.20	Tucker		+ 0.22
"	1.55	0.96	Phila.		+ 0.59
"	1.21	1.63	Newburgh	I	- 0.42
"	1.21	0.64	"	II	+ 0.43
"	1.49	1.15	Flint	I	+ 0.34
"	1.49	1.05	"	II	+ 0.44
"	2.33	2.12	Ajax	I	+ 0.21
"	2.33	1.91	"	II	+ 0.42
Panels not		1.96	Toledo	I	
returned		2.32	"	II	
		1.49	"	III	
ΔG	1.07	1.15	So.S.F.	I	- 0.08
"	1.07	.60	"	II	+ 0.47
"	.70	.75	Parlin	I	- 0.05
"	.70	.08	"	II	+ 0.62
"	.70	.57	"	III	+ 0.13

All of the panels sent to the plants were made from the same material and on the same day using the automatic spray gun. The panels when read on the Process Engineering colormaster should have had the same ΔG values, but note the variance from 0.70 to 2.33. This indicates a weakness in reproducibility of the test. The panels were made in "Duco"* similar to the method used to make the present gloss versus color study.

(*) Du Pont Registered Trademark

EXHIBIT C (Cont'd)

Parlin reported that they could get smaller differences in ΔG between colormasters if they used the spinner.

The large aperture was also used to evaluate panels with the following results on two colormasters:

	P.E.	Marshall Lab.		
ΔG	1.70	1.38	+ 0.32	(Ajax Panels)
	.81	0.50	+ 0.31	(Phila. Panels)

The same panels measured on the Marshall Laboratory colormaster on the regular port were as follows:

ΔG	2.17	(Ajax Panels)
ΔG	1.39	(Phila. Panels)

The large aperture decreases the ΔG values but did not eliminate differences between colormasters.

The only solution to date is to raise the gloss of the flat panel.

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