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MANUFACTURERS COUNCIL ON COLOR AND APPEARANCE

COLLABORATIVE REFERENCE PROGRAM

COLOR AND APPEARANCE

COLOR AND COLOR DIFFERENCE

REPORT NO. 27



U.S. DEPARTMENT OF COMMERCE

National Bureau of Standards

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NBS COLLABORATIVE REFERENCE PROGRAMS

TAPPI Paper and Board (6 times per year)

Bursting strength	Smoothness
Tearing strength	Surface pick strength
Tensile breaking strength	K & N ink absorption
Elongation to break	pH
Tensile energy absorption	Opacity
Folding endurance	Blue reflectance (brightness)
Stiffness	Specular gloss, 75°
Air resistance	Thickness
Grammage	Concora (flat crush)
	Ring crush

FKBG-API Containerboard (48 times per year)

Mullen burst of linerboard
Concora test of medium

MCCA Color and Appearance (4 times per year)

Gloss at 60°
Color and color difference

CTS Rubber (4 times per year)

Tensile strength, ultimate elongation and tensile stress
Hardness
Mooney viscosity
Vulcanization properties

CTS Thermal Insulation Materials (2 times per year)

19 test methods for thermal insulation materials covering:
thermal properties; strength properties; dimensions, stability,
and density properties; fire properties; and properties of
vapor barriers

ASTM Cement (2 times per year)

Chemical (11 chemical components)
Physical (8 characteristics)

AASHTO Bituminous

Asphalt cement (2 times per year)
Cutbacks (once a year)

NBS Collaborative Reference Programs
A05 Technology Building
National Bureau of Standards
Washington, DC 20234

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**MANUFACTURERS COUNCIL ON
COLOR AND APPEARANCE**

**COLLABORATIVE REFERENCE PROGRAM
FOR
COLOR AND APPEARANCE**

COLOR AND COLOR DIFFERENCE

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Office of Engineering Standards
National Engineering Laboratory**

**U. S. DEPARTMENT OF COMMERCE
National Bureau of Standards**

INTRODUCTION

This Collaborative Reference Program is sponsored by the Manufacturers Council on Color and Appearance and the National Bureau of Standards. Four times per year, color chip samples are distributed to each participating laboratory. After the data has been returned to and analyzed by NBS, a report (as illustrated by this report) showing the data from all participants is prepared.

Reflectance values for 40 wavelengths and colorimetric data for 45/0 reflectance factor have been provided by NBS. For further explanation, see page 20. A plot of the spectrophotometric curves of the samples was provided by Hemmendinger Color Laboratory, Belvedere, New Jersey. The NBS Reflectance values have succeeded the tentative values which were given in previous reports.

If there are any questions on the notes, the analyses, or the report in general, contact J. Horlick on 301-921-2946.

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KEY TO TABLES

MEAN	The average of individual test determinations.
GRAND MEAN - (GR. MEAN)	The average of the individual laboratory MEANS, excluding laboratories flagged (see column F) with an X, #, or +.
SD OF MEANS -	The standard deviation of the laboratory MEANS about the GRAND MEAN: an index of the among-laboratory precision.
INST CODE -	Code for instrument type and color space used to report measurements, see first table.
F -	Flag, is based on ΔE Column with following meaning:
# -	Excluded because data were not understood; because of a non-coded variation reported by the laboratory or data received late.
M -	Excluded because data for one sample are missing
X -	Excluded from all calculations because ΔE is beyond (3) standard deviation units.
* -	Included in grand means but results are between two and three standard deviation units. The participant should take this as a warning to reexamine his testing procedure.
0 -	Included in grand mean analysis.

Note: In addition to flag (F) based on delta E column it is also possible to have either a X or an * on individual MEANS as follows:

X - following a MEAN signifies that the mean is greater than 3 SD of MEANS from the GRAND MEAN. The values for this laboratory have been omitted in the calculations involving the MEAN for the column.

* - following any of the MEANS signifies that that quantity is greater than 2 but less than 3 of the appropriate standard deviations from the corresponding average. The participant should take this as a warning to reexamine his testing procedures.

ΔE - Total color difference between two samples. In X, Y, Z analysis it is calculated in MacAdams (FMC II) units. For L, a, b analysis it is calculated in Hunter units.

ΔE Calculation

ΔE is calculated in the Color and Color Difference Collaborative Reference Program by the FMC2* equations (X, Y, Z analysis) as follows:

The yellow-blue chromatic difference is

$$\Delta C_1 = K_1 S(P\Delta P + Q\Delta Q)/bD^2 - K_1 \Delta S/b;$$

the lightness difference is

$$\Delta L = 0.279K_2(P\Delta P + Q\Delta Q)/aD;$$

and the red-green chromatic difference is

$$\Delta C_3 = K_1(Q\Delta P - P\Delta Q)/aD.$$

The quantity, D, is an abbreviation,

$$D = (P^2 + Q^2)^{\frac{1}{2}}.$$

$$K_1 = 0.55669 + 0.049434 Y - 0.82575 \cdot 10^{-3} Y^2 + \\ 0.79172 \cdot 10^{-5} Y^3 - 0.30087 \cdot 10^{-7} Y^4,$$

$$K_2 = 0.17548 + 0.027556 Y - 0.57262 \cdot 10^{-3} Y^2 + \\ 0.63893 \cdot 10^{-5} Y^3 - 0.26731 \cdot 10^{-7} Y^4,$$

$$a^2 = 17.3 \cdot 10^{-6} (P^2 + Q^2) / [1 + 2.73 P^2 Q^2 / (P^4 + Q^4)],$$

$$b^2 = 3.098 \cdot 10^{-4} (S^2 + 0.2015 Y^2)$$

$$P = 0.724 X + 0.382 Y - 0.098 Z,$$

$$Q = -0.48 X + 1.37 Y + 0.1276 Z,$$

$$S = 0.686 Z,$$

$$\Delta E = [(\Delta C_1)^2 + (\Delta L)^2 + (\Delta C_3)^2]^{\frac{1}{2}}$$

*Friele-MacAdam-Chickering metric

Notes on Specific Laboratory Results

- C213, C285 - Apparently measured the back of all five samples
- C451 - Reported extreme values compared to other labs for four colored samples
- C534 - Reported extreme values compared to other labs for samples D03 and D04
- C521A, C521B, C543 - Data included in body of report, but received too late for checking and therefore not used in statistical computation
- C644 - Apparent reporting or measurement problem
- C699 - The value for MEAN X for sample D01 was incorrectly entered into the computer. The correct value, 49.85, would not cause the laboratory to receive an X flag.

ANALYSIS C70-1 TABLE 1
CØLØR & CØLØR DIFFERENCE

INSTRUMENT IDENTIFICATION

INST CØDE	INSTRUMENT	CØLØR SPACE	DATA CØDE
-----	-----	-----	-----
C70AC	ACS SPECTRA SENSOR	X Y Z	9014
C70BL	B*L 505 SPECTRØPBØTØMETER	X Y Z	9014
C70CA	CARY 14	X Y Z	9014
C70CD	CØLØR EYE SMALL SPHERE	X Y Z	9014
C70CE	CØLØR EYE SMALL SPHERE	XX ¹ YZ,4V	9016
C70CF	CØLØR EYE SMALL SPHERE	XYZ,BaSØ4	9017
C70CG	CØLØR EYE SMALL SPHERE	XX ¹ YZ,Ba	9018
C70CH	CØLØR EYE SMALL SPHERE	XYZ,3V	9011
C70CL	CØLØR EYE LARGE SPHERE	XX ¹ YZ,4V	9016
C70CN	CØLØR EYE LARGE SPHERE	XX ¹ YZ,Ba	9018
C70CN	CØLØR EYE LARGE SPHERE	XYZ,BaSØ4	9017
C70DC	DIANØ CHRØMASCAN SPECTRØPBØTØMETER	X Y Z	9014
C70DE	DIANØ NAICB SCAN SPECTRØPBØTØMETER	X Y Z	9014
C70DK	DIANØ/LSC AUTØMATE	XYZ,BaSØ4	9017
C70DL	DIANØ/LSC AUTØMATE	XYZ,3V,4F	9019
C70DM	DIANØ/LSC AUTØMATE	XX ¹ YZ,4V	9016
C70DS	DIANØ/SSCE AUTØMATE	XX ¹ YZ,Ba	9018
C70DI	DIANØ/SSCE AUTØMATE	XYZ,BaSØ4	9017
C70GA	GARDNER AUTØ AC2/AC3	L a b	9013
C70GB	GARDNER AUTØ AC2/AC3	X Y Z	9014
C70GC	GARDNER XL-20/XL-30 SERIES	X Y Z	9014
C70GD	GARDNER XL-20/XL-30 SERIES	L a b	9013
C70GE	GE/DIANØ/HARDY SPECTRØPBØTØMETER	X Y Z	9014
C70GK	GARDNER XL-70	X Y Z	9014
C70GL	GARDNER XL-70	L a b	9013
C70GN	GARDNER MULTIPURPOSE REFLECTØMETER	X Y Z	9014
C70GP	GARDNER XL-200 SERIES	L a b	9013
C70GX	GARDNER XL-10	L a b	9013
C70GY	GARDNER XL-10	X Y Z	9014
C70HA	HUNTER D25A (DA,D1A,D2A)	L a b	9013
C70BB	HUNTER D25A (DA,D1A,D2A)	X Y Z	9014
C70BF	HUNTER D25AA	L a b	9013
C70BG	HUNTER D25AA	X Y Z	9014
C70HM	HUNTER D25M (DM,D1M,D2M)	L a b	9013
C70BN	HUNTER D25M (DM,D1M,D2M)	X Y Z	9014
C70FP	HUNTER D25P (DP,D1P,D2P)	X Y Z	9014
C70HQ	HUNTER D25P (DP,D1P,D2P)	L a b	9013
C70HR	HUNTER D25A (DA,D1A,D2A)	Rd a b	9012
C70HI	HUNTER D54 SPECTRØPBØTØMETER	X Y Z	9014
C70HU	HUNTER D54 SPECTRØPBØTØMETER	L a b	9013
C70IB	IBM SPECTRØPBØTØMETER	X Y Z	9014
C70KC	KCS-18	XX ¹ YZ,4V	9016
C70KD	KCS-18	XX ¹ YZ,Ba	9018
C70KS	KCS-18	X Y Z	9014
C70KI	KCS-40	X Y Z	9014
C70LS	LERES TRILAC	X Y Z	9014
C70LT	LERES TRILAC	XYZ,3V	9011
C70WD	MACBETH MS2000 SPECTRØPBØTØMETER	X Y Z	9014
C70ME	MACBETH MS2000 SPECTRØPBØTØMETER	L a b	9013
C70MG	MACBETH MC1010	L a b	9013
C70MH	MACBETH MC1010	X Y Z	9014
C70MS	MARTIN SWEETS	X Y Z	9014
C70MT	MARTIN SWEETS	XX ¹ YZ,Ba	9018
C70ND	NEØTEC 220 DU CØLØR	R G B	9015
C70NE	NEØTEC 220 DU CØLØR	X Y Z	9014
C70SA	SPECIAL INSTRUMENT - INCLUDED	X Y Z	9014
C70SB	SPECIAL INSTRUMENT - INCLUDED	Rd a b	9012
C70SC	SPECIAL INSTRUMENT - INCLUDED	L a b	9013
C70SL	SPECIAL INSTRUMENT - INCLUDED	R G B	9015
C70SP	SPECIAL INSTRUMENT - EXCLUDED	X Y Z	9014
C70SQ	SPECIAL INSTRUMENT - EXCLUDED	Rd a b	9012
C70SR	SPECIAL INSTRUMENT - EXCLUDED	L a b	9013
C70SS	SPECIAL INSTRUMENT - EXCLUDED	R G B	9015
C70ZD	ZEISS DMC25	X Y Z	9014
C70ZE	ZEISS ELREPHØ	X Y Z	9014
C70ZF	ZEISS ELREPHØ	R G B	9015
C70XX	GIVE INSTRUMENT MAKE*ØDEL.	NOT SPECIFIED	9020

FORMAT OF CØLØRIMETRIC (INPUT) DATA

DATA CØDE	CØLØR SCALE
-----	-----
9011	X,Y,Z 3 FUNCTION VITRØLITE CØRRECTION
9012	Rd,a,b
9013	L,a,b HUNTER
9014	X,Y,Z
9015	R,G,B
9016	X,X ¹ ,Y,Z 4 FUNCTION VITRØLITE CØRRECTION
9017	X,Y,Z, BaSØ4 CØRRECTION
9018	X,X ¹ ,Y,Z BaSØ4 CØRRECTION
9019	X,Y,Z 4 FUNCTION VITRØLITE CØRRECTION
9020	(NON-STD. INST. SCALE SPECIFIED WITH DATA)

LAB CODE	F	SAMPLE D01			SAMPLE D02			DIFFERENCE D02 - D01			ΔE	INST CODE	LAB
		MEAN X	MEAN Y	MEAN Z	MEAN X	MEAN Y	MEAN Z	ΔX	ΔY	ΔZ			
C646	Ø	54.93X	48.90X	53.62*	54.12X	47.90X	53.50X	-0.81	-1.00	-0.12	2.29	70CG	C646
C656	Ø	49.65	42.07	50.98	48.68	41.02	50.69	-0.97	-1.05	-0.29	2.40	70SA	C656
C657	Ø	48.55	42.18	46.43X	47.65	41.17	46.20X	-0.90	-1.01	-0.24	2.33	70AC	C657
C660	Ø	49.10	42.66	47.01X	48.22	41.68	46.83X	-0.88	-0.98	-0.19	2.26	70AC	C660
C662	Ø	48.55	41.85	46.91X	47.47	40.66	46.51X	-1.08	-1.18	-0.40	2.66	70DH	C662
C664	Ø	48.00	40.21*	48.87*	46.95*	39.07*	48.46*	-1.05	-1.15	-0.41	2.70	70KC	C664
C671A	Ø	49.55	41.89	50.50	48.46	40.72	50.06	-1.09	-1.18	-0.43	2.63	70DH	C671A
C671B	Ø	49.72	41.98	49.97	48.64	40.81	49.54	-1.07	-1.16	-0.43	2.62	70DH	C671B
C671C	Ø	50.73	40.35	50.31	49.63	39.23*	49.91	-1.11	-1.12	-0.41	2.56	70GC	C671C
C671D	Ø	49.41	41.93	51.36	48.37	40.83	51.02	-1.05	-1.11	-0.34	2.45	70HB	C671D
C672	Ø	49.90	42.30	51.20	48.80	41.15	50.80	-1.10	-1.15	-0.40	2.49	70GC	C672
C675	Ø	50.34	42.62	51.07	49.34	41.53	50.80	-1.00	-1.09	-0.27	2.49	70SA	C675
C683	Ø	47.77*	39.75*	48.02X	46.61*	38.53*	47.56X	-1.16	-1.22	-0.46	2.79	70GC	C683
C691	Ø	49.46	41.60	50.14	48.42	40.49	49.65	-1.04	-1.12	-0.49	2.47	70SA	C691
C699	X	49.35	42.42	51.37	48.73	41.21	50.86	-0.62 X	-1.21	-0.51	5.50X	70BL	C699
C700	Ø	50.84	42.84	52.26	45.80	41.70	51.91	-1.04	-1.14	-0.35	2.56	70DH	C700
GRAND MEANS		46.85	42.16	51.15	48.83	41.05	50.75	-1.06	-1.14	-0.37	2.64		
SD OF MEANS		.96	.92	.88	.94	.89	.82	.13	.14	.16	.31		
INCLUDED LABS FOR THIS MEAN		72	72	68	72	72	67	72	73	73	74		

LAB CODE	F	SAMPLE D03			SAMPLE D04			DIFFERENCE D04 - D03			INST CODE	LAB
		MEAN X	MEAN Y	MEAN Z	MEAN X	MEAN Y	MEAN Z	ΔX	ΔY	ΔZ		
C157	θ	9.44	11.89	6.01X	9.41	11.90	6.14X	-0.03	0.01	0.13	1.42*	70GE C157
C162	θ	9.72	12.30	7.62	9.58	12.21	7.69	-0.14	-0.09	0.06	1.90	70DC C162
C232	θ	10.23*	13.05X	8.23*	10.00*	12.86X	8.22*	-0.23	-0.19	-0.01	2.09	70CE C232
C244	X	9.02	11.45*	6.67	8.84*	11.45	6.70	-0.18	0.00	0.03	3.65X	70ZE C244
C250	θ	9.47	12.20	7.44	9.31	12.10	7.44	-0.16	-0.10	0.00	1.82	70ZF C250
C251	X	9.48	11.80	7.08	9.24	11.70	7.09	-0.24	-0.10	0.00	3.45X	70ZE C251
C396	X	10.55X	11.45*	6.55*	10.40X	11.25*	6.50*	-0.15	-0.20	-0.05	0.94X	70GY C396
C407	θ	9.71	12.21	7.30	9.57	12.15	7.35	-0.14	-0.06	0.05	2.10	70SA C407
C414	θ	9.45	11.87	7.03	9.27	11.74	7.02	-0.18	-0.13	-0.00	1.88	70MD C414
C416A	θ	9.61	12.05	7.10	9.43	11.91	7.19	-0.18	-0.14	0.09	2.28	70GE C416A
C416B	θ	9.75	11.98	6.76	9.57	11.84	6.78	-0.19	-0.14	0.02	1.92	70SA C416B
C418	θ	9.43	12.02	7.17	9.29	11.92	7.29	-0.14	-0.09	0.12	2.18	70CE C418
C422	θ	9.27	11.65	6.75	9.00	11.40*	6.71	-0.27 *	-0.25 *	-0.03	2.05	70SA C422
C424	θ	9.88	12.39	7.67	9.71	12.28	7.69	-0.17	-0.11	0.01	2.02	70CA C424
C428	θ	9.59	12.05	7.13	9.42	11.93	7.16	-0.17	-0.12	0.02	1.93	70HB C428
C437	θ	9.55	12.25	7.16	9.44	12.17	7.31	-0.11	-0.09	0.15	1.88	70CE C437
C444	θ	9.56	12.05	7.36	9.49	12.03	7.52	-0.07	-0.02	0.17	1.95	70GE C444
C445	θ	9.82	12.25	7.78	9.70	12.16	7.92	-0.12	-0.10	0.14	1.91	70LS C445
C446A	θ	9.61	12.03	7.42	9.47	11.95	7.51	-0.13	-0.08	0.09	2.06	70GE C446A
C451	#	22.15X	12.00	20.08X	21.94X	11.93	20.17X	-0.21	-0.07	0.09	1.70	70AC C451
C453	θ	9.72	11.97	7.09	9.55	11.87	7.08	-0.17	-0.10	-0.01	1.89	70HT C453
C455	θ	9.53	12.04	7.05	9.56	12.17	7.28	0.03 *	0.13 *	0.23 *	2.12	70KS C455
C459	θ	9.36	11.79	7.10	9.22	11.72	7.13	-0.14	-0.08	0.03	1.94	70GE C459
C460	θ	9.16	11.66	6.98	8.97	11.52	6.95	-0.19	-0.13	-0.03	1.95	70GE C460
C462A	θ	9.50	11.85	6.90	9.40	11.75	7.00	-0.10	-0.10	0.10	1.36*	70SA C462A
C463	θ	9.56	12.10	7.38	9.47	12.06	7.47	-0.09	-0.04	0.08	1.74	70ZD C463
C467A	θ	9.85	12.15	7.50	9.81	12.18	7.65	-0.04	0.03	0.15	1.87	70GE C467A
C467B	θ	9.43	11.80	6.92	9.38	11.83	7.04	-0.05	0.03	0.13	1.96	70HN C467B
C469	θ	9.93	12.31	7.72	9.80	12.25	7.79	-0.13	-0.07	0.06	1.88	70GE C469
C470	θ	9.58	12.14	7.49	9.54	12.18	7.55	-0.04	0.04	0.06	1.70	70GE C470
C472	θ	9.34	11.93	7.27	9.23	11.87	7.40	-0.12	-0.06	0.13	2.12	70KS C472
C473	θ	9.54	12.03	7.35	9.41	11.97	7.37	-0.13	-0.06	0.01	1.74	70DH C473
C474	θ	9.17	11.58	6.94	9.11	11.61	6.97	-0.06	0.03	0.03	1.71	70GE C474
C476	θ	9.21	11.62	7.47	9.10	11.60	7.48	-0.11	-0.02	0.01	1.97	70SA C476
C479A	X	7.25X	9.70X	6.20X	7.30X	9.80X	6.20X	0.05 *	0.10 *	-0.00	0.62X	70GB C479A
C479B	θ	9.86	12.41	7.84	9.76	12.38	7.91	-0.10	-0.03	0.07	1.71	70CA C479B
C480	θ	9.72	12.14	7.23	9.64	12.15	7.25	-0.07	0.01	0.02	1.76	70HB C480
C481	X	9.65	12.10	7.15	9.55	12.05	7.10	-0.10	-0.05	-0.05	1.12X	70HB C481
C483	θ	9.58	11.80	7.20	9.43	11.70	7.20	-0.16	-0.10	0.00	1.80	70ZF C483
C495	θ	9.70	12.16	7.40	9.59	12.09	7.52	-0.11	-0.07	0.12	1.87	70KS C495
C496A	θ	9.65	12.15	7.35	9.54	12.09	7.45	-0.11	-0.06	0.11	1.89	70GE C496A
C499C	θ	10.35*	12.71*	7.75	10.05*	12.47	7.71	-0.30 *	-0.25 *	-0.04	2.44*	70BL C499C
C503	θ	9.45	11.94	7.31	9.29	11.84	7.32	-0.17	-0.11	0.01	1.98	70GE C503
C508	θ	9.54	11.94	7.27	9.48	11.94	7.39	-0.06	0.00	0.12	1.74	70SA C508
C511	θ	9.63	12.12	7.36	9.41	11.95	7.33	-0.22	-0.16	-0.03	2.00	70DH C511
C521A	#	9.80	12.28	7.35	9.65	12.18	7.40	-0.14	-0.10	0.05	1.80	70CA C521A
C521B	#	9.24	11.37*	7.09	8.90*	11.09X	6.87	-0.35 X	-0.27 *	-0.22 X	2.54*	70SA C521B
C522	X	9.10	11.80	6.50*	8.90*	11.70	6.60*	-0.20	-0.10	0.10	3.15X	70SA C522
C524	θ	10.12	12.60*	7.89	10.01*	12.56*	7.96	-0.10	-0.04	0.06	1.77	70GE C524
C528	θ	9.78	12.23	7.54	9.63	12.14	7.54	-0.15	-0.09	0.00	1.83	70HT C528
C534	#	15.42X	17.50X	15.09X	15.24X	17.37X	15.05X	-0.18	-0.13	-0.04	1.31*	70MD C534
C540	θ	10.18*	12.62*	7.89	9.98*	12.48	7.86	-0.20	-0.14	-0.03	1.97	70GE C540
C545	θ	8.94*	11.29*	6.74	8.86*	11.27*	6.80	-0.08	-0.01	0.06	1.72	70GE C545
C549	θ	9.62	12.09	7.36	9.52	12.07	7.42	-0.10	-0.03	0.06	1.88	70DH C549
C552	θ	11.71X	9.36X	6.85	11.74X	9.31X	6.94	0.02 *	-0.05	0.09	1.48	70HN C552
C608	θ	12.54X	10.03X	7.56	12.52X	9.94X	7.67	-0.02	-0.09	0.11	1.42*	70GC C608
C612	X	9.22	11.73	7.07	9.08	11.59	6.91	-0.14	-0.14	-0.16 X	0.75X	70GE C612
C613	θ	8.92*	11.95	5.79X	8.83*	11.92	5.91X	-0.09	-0.03	0.13	1.97	70MD C613
C627	θ	9.61	12.02	7.26	9.56	12.05	7.37	-0.05	0.03	0.12	1.79	70SA C627
C630	θ	9.42	12.13	6.84	9.25	12.03	6.82	-0.17	-0.10	-0.01	1.84	70KS C630
C631A	θ	9.53	11.94	7.26	9.45	11.92	7.37	-0.07	-0.02	0.11	1.74	70AC C631A
C634	θ	9.44	11.91	7.17	9.35	11.87	7.24	-0.10	-0.04	0.07	1.65	70CE C634
C638	θ	9.10	11.60	6.70	9.00	11.60	6.80	-0.10	0.00	0.10	2.44*	70GC C638
C639	θ	9.49	11.97	7.42	9.40	11.94	7.51	-0.09	-0.03	0.09	1.79	70SA C639
C645	θ	9.69	12.07	7.37	9.55	11.99	7.40	-0.14	-0.08	0.03	1.84	70HB C645

LAB CODE	F	SAMPLE D03			SAMPLE D04			DIFFERENCE D04 - D03			ΔE	INST CODE	LAB
		MEAN X	MEAN Y	MEAN Z	MEAN X	MEAN Y	MEAN Z	ΔX	ΔY	ΔZ			
C646	Ø	9.21	12.00	7.58	9.08	11.90	7.57	-0.13	-0.10	-0.01	1.29*	70CG C646	
C656	Ø	9.63	11.98	7.18	9.38	11.80	7.05	-0.25 *	-0.18	-0.13 X	2.09	70SA C656	
C657	Ø	9.39	12.05	6.85	9.31	12.04	6.93	-0.07	-0.01	0.08	1.67	70AC C657	
C660	Ø	9.52	12.24	6.87	9.45	12.24	6.98	-0.07	-0.00	0.11	1.77	70AC C660	
C662	Ø	9.27	11.92	6.72	9.20	11.92	6.81	-0.07	-0.00	0.08	1.69	70DH C662	
C664	Ø	9.27	11.80	7.01	9.25	11.85	7.13	-0.02	0.05	0.12	1.59	70KC C664	
C671A	Ø	9.53	11.93	7.28	9.34	11.78	7.27	-0.19	-0.14	-0.01	1.95	70DH C671A	
C671B	Ø	9.31	11.79	7.26	9.24	11.78	7.39	-0.06	-0.01	0.13	1.79	70DH C671B	
C671C	Ø	9.49	11.39*	6.83	9.33	11.32*	6.84	-0.15	-0.07	0.01	2.20	70GC C671C	
C671D	Ø	9.58	12.01	6.99	9.48	12.01	7.10	-0.10	0.00	0.12	2.46*	70HB C671D	
C672	Ø	9.80	12.20	7.50	9.80	12.30	7.60	0.00	0.10 *	0.10	1.74	70GC C672	
C675	Ø	9.62	12.04	7.34	9.61	12.11	7.48	-0.01	0.07	0.15	1.77	70SA C675	
C683	Ø	8.46X	10.87X	6.53*	8.46X	10.96X	6.71	0.00	0.09	0.18	1.92	70GC C683	
C691	Ø	9.75	11.89	7.56	9.67	11.88	7.64	-0.09	-0.01	0.08	1.83	70SA C691	
C699	Ø	9.58	12.45	7.87	9.88	12.44	7.96	-0.09	-0.01	0.09	1.59	70BL C699	
C700	Ø	9.81	12.32	7.56	9.64	12.18	7.66	-0.17	-0.14	0.10	2.11	70DH C700	
GRAND MEANS													
		9.58	12.03	7.28	9.46	11.98	7.34	-0.11	-0.06	0.07	1.88		
SD OF MEANS													
		0.27	0.26	0.34	0.26	0.26	0.34	0.07	0.07	0.06	0.23		
INCLUDED LABS FOR THIS MEAN													
		67	66	68	67	66	68	70	70	69	70		

EXPLANATION OF DATA FOR WHITE SAMPLE

Specimens of a white sample were distributed to the participants along with the usual two pairs of colored specimens, and each participant was asked to return measurement data for the white specimen, reporting results in the same manner as for the colored specimens.

As a first step, three laboratories were selected to serve as "reference" laboratories for the purposes of this analysis and the average of their X, Y, Z values for the white sample were computed. Next, the ratios of the participants data to the combined reference laboratory values were calculated for each participant (transformed to X, Y, Z space if necessary). These ratios are shown in the White Sample Analysis tables.

Two observations can be made about the data in the White Sample Analysis tables. First, the participants as a whole tend to be high compared with the combined average values obtained by the selected reference laboratories. Second, a few participants had noticeably extreme values for one or more of the components and these participants especially should look to the cause.

Next, the ratios in the White Sample Analysis tables were used to "adjust" the data of the normal data tables to obtain the adjusted data table values. The adjustment consisted of dividing the X, Y, Z values of the normal data tables by the respective ratios in the White Sample Analysis tables.

The significant change in the adjusted data tables is in the SD OF MEANS. Comparison of these among-laboratory standard deviations with those in the normal data tables, shows considerable reduction for X, Y, Z. Thus part, at least, of the disagreement among participants is due to errors in standardization that could be corrected through use of an agreed-upon white standard. There is no similar significant change for ΔX , ΔY , and ΔZ .

LAB CODE	RATIO--(LAB/COMBINED)			INST CODE	PERCENT FROM COMBINED		
	X	Y	Z		X	Y	Z
C157	1.0148	1.0127	1.0144	70GE	1.48	1.27	1.44
C162	1.0167	1.0132	1.0173	70DC	1.67	1.32	1.73
C232	1.0080	1.0058	1.0226	70CE	.80	.58	2.26
C244	1.0029	1.0007	1.0050	70ZE	.29	.07	.50
C250	1.0032	.5953	.5982	70ZF	.32	-.07	-.18
C251	1.0052	1.0059	1.0073	70ZE	.92	.59	.73
C396	1.0177	.5679	.5914	70GY	1.77	-3.21	-.86
C407	1.0142	1.0131	1.0174	70SA	1.42	1.31	1.74
C414	.5925	.5934	.5823	70MD	.75	-.66	-1.77
C416A	1.0255	1.0253	1.0214	70GE	2.55	2.53	2.14
C416B	1.0531	1.0527	1.0217	70SA	5.31	5.27	2.17
C418	.5853	.5822	.5997	70CE	-1.47	-1.78	-.03
C422	.5954	.5918	.5877	70SA	-.46	-.82	-1.23
C424	1.0059	1.0104	1.0136	70CA	.99	1.04	1.36
C428	1.0080	1.0057	1.0110	70BB	.80	.57	1.10
C437	1.0150	1.0104	1.0278	70CE	1.50	1.04	2.78
C444	1.0138	1.0145	1.0172	70GE	1.38	1.45	1.72
C445	1.0055	1.0053	1.0144	70LS	.55	.53	1.44
C446A	1.0043	1.0037	1.0063	70GE	.43	.37	.63
C451	1.0133	1.0130	1.0043	70AC	1.33	1.30	.43
C453	1.0125	1.0121	1.0059	70BT	1.25	1.21	.59
C455	.5776	.5718	.5808	70KS	-2.24	-2.82	-1.92
C459	.5957	.5963	.5937	70GE	-.43	-.37	-.63
C460	1.0083	1.0054	1.0083	70GE	.83	.94	.83
C462A	.5956	.5988	1.0053	70SA	-.04	-.12	.53
C463	1.0105	1.0085	1.0134	70ZD	1.09	.89	1.34
C467A	1.0052	1.0114	1.0123	70GE	.92	1.14	1.23
C467B	1.0014	.9972	1.0032	70BN	.14	-.28	.32
C469	1.0163	1.0154	1.0229	70GE	1.63	1.54	2.29
C470	1.0159	1.0203	1.0288	70GE	1.59	2.03	2.88
C472	.5965	.5955	.5954	70KS	-.35	-.45	-.46
C473	1.0076	1.0063	1.0034	70DB	.76	.63	.34
C474	1.0054	1.0064	1.0071	70GE	.54	.64	.71
C476	1.0172	1.0158	1.0163	70SA	1.72	1.58	1.63
C479A	.8405	1.0043	.9899	70GB	-15.95	.43	-1.01
C479B	1.0358	1.0358	1.0400	70CA	3.58	3.58	4.00
C480	1.0105	1.0080	1.0139	70BB	1.05	.80	1.39
C481	1.0052	1.0065	1.0105	70BB	.92	.65	1.05
C483	.5990	.5982	.5994	70ZF	-.10	-.18	-.06
C495	1.0127	1.0130	1.0079	70KS	1.27	1.30	.75
C496A	1.0177	1.0191	1.0149	70GE	1.77	1.91	1.49
C499C	1.0313	1.0322	1.0345	70BL	3.13	3.22	3.45
C503	1.0215	1.0219	1.0256	70GE	2.15	2.19	2.56
C508	1.0077	1.0085	1.0069	70SA	.77	.89	.69
C511	1.0061	1.0060	1.0030	70DB	.61	.60	.30
C521A	1.0156	1.0165	1.0192	70CA	1.56	1.65	1.92
C521B	1.0328	1.0321	1.0298	70SA	3.28	3.21	2.98
C522	.5956	.5982	.5933	70SA	-.04	-.18	-.67
C524	1.0261	1.0265	1.0243	70GE	2.61	2.65	2.43
C528	1.0130	1.0122	1.0063	70BT	1.30	1.22	.63
C534	.5883	.5884	.5821	70MD	-1.17	-1.16	-1.79
C540	1.0116	1.0117	1.0094	70GE	1.16	1.17	.94
C545	.5750	.5764	.5777	70GE	-2.50	-2.36	-2.23
C549	1.0100	1.0073	1.0072	70DB	1.00	.73	.72
C552	.5983	.5958	1.0027	70BN	-.17	-.42	.27
C608	1.0188	.5715	.5910	70GC	1.88	-2.85	-.90
C612	1.0053	1.0103	1.0097	70GE	.93	1.03	.97
C613	1.0216	1.0221	1.0158	70MD	2.16	2.21	1.98
C627	1.0008	.5990	.5958	70SA	.08	-.10	-.42
C630	.5760	1.0055	.5305	70KS	-2.40	.55	-6.95
C631A	1.0155	1.0143	1.0080	70AC	1.55	1.43	.80
C634	.5871	.5820	.5830	70CE	-1.29	-1.80	-1.70
C638	.5991	.5982	.5962	70GC	-.05	-.18	-.38
C639	.5998	.5977	1.0040	70SA	-.02	-.23	.40
C645	1.0122	1.0115	1.0047	70BB	1.22	1.15	.47
C646	1.0136	1.0142	1.0276	70CO	1.36	1.42	2.76
C656	1.0019	1.0015	.5936	70SA	.19	.15	-.64
C657	.5776	1.0080	.5918	70AC	-2.24	.80	-8.02
C660	.5812	1.0125	.5927	70AC	-1.88	1.29	-7.03
C662	.5713	.5947	.5217	70DB	-2.87	-.53	-7.83
C664	.5676	.5906	.5637	70IC	-3.24	-3.94	-3.63
C671A	.5933	.5925	.5867	70DB	-.67	-.71	-1.33
C671B	.5961	.5947	.5909	70DB	-.39	-.53	-.91
C671C	.5916	.5992	.5901	70GC	-.84	-.08	-.99
C671D	1.0070	1.0048	1.0115	70BB	.70	.46	1.15
C672	1.0024	1.0015	.5966	70GC	.24	.15	-.34
C675	1.0167	1.0156	1.0055	70SA	1.67	1.56	.95
C683	1.0103	1.0077	.5954	70GC	1.03	.77	-.06
C691	.5950	.5934	.5983	70BA	-.10	-.66	-.17
C695	.5946	.5978	.5928	70BL	-.54	-.22	-.72
C700	1.0240	1.0204	1.0265	70DB	2.40	2.04	2.65

LAB CODE	FATIO--(LAB/COMBINED)			INST CODE	PERCENT FROM COMBINED		
	X	Y	Z		X	Y	Z
C105	0.9798	0.9767	0.9874	70HM	-2.02	-2.33	-1.26
C121	0.9822	0.9767	0.9934	70HM	-1.78	-2.33	-0.66
C122	0.9761	0.9737	0.9835	70SC	-2.39	-2.63	-1.65
C148	0.9844	0.9819	0.9888	70HA	-1.56	-1.81	-1.12
C150	0.9843	0.9830	0.9921	70HA	-1.57	-1.70	-0.79
C152	0.9903	0.9860	0.9961	70HA	-0.97	-1.40	-0.39
C166	0.9875	0.9850	0.9942	70HA	-1.25	-1.50	-0.58
C183	0.9864	0.9842	0.9907	70SC	-1.36	-1.58	-0.93
C213	0.9207	0.9161	0.9006	70SC	-7.93	-8.39	-9.94
C223	0.9974	0.9928	1.0052	70HA	-0.26	-0.72	0.52
C230	0.9841	0.9811	0.9923	70HA	-1.59	-1.89	-0.77
C241	0.9857	0.9829	0.9929	70SC	-1.43	-1.71	-0.71
C255	0.9841	0.9819	0.9911	70HA	-1.59	-1.81	-0.89
C256A	0.9782	0.9757	0.9863	70HA	-2.18	-2.43	-1.37
C256B	0.9904	0.9891	0.9887	70HU	-0.96	-1.09	-1.13
C259	0.9807	0.9788	0.9857	70HA	-1.93	-2.12	-1.43
C262	0.9953	0.9918	1.0023	70SB	-0.47	-0.82	0.23
C285	0.9307	0.9261	0.9121	70HA	-6.93	-7.39	-8.79
C288	0.9915	0.9901	0.9965	70HA	-0.85	-0.99	-0.35
C291	0.9853	0.9839	0.9902	70HA	-1.47	-1.61	-0.98
C317	0.9742	0.9706	0.9811	70HM	-2.58	-2.94	-1.89
C320	0.9926	0.9911	0.9974	70SC	-0.74	-0.89	-0.26
C325	0.9866	0.9845	0.9913	70HR	-1.34	-1.55	-0.87
C340	0.9854	0.9820	0.9951	70SC	-1.46	-1.80	-0.49
C352	0.9897	0.9860	1.0014	70HA	-1.03	-1.40	0.14
C356	0.9757	0.9726	0.9847	70HM	-2.43	-2.74	-1.53
C380	0.9879	0.9860	0.9945	70HA	-1.21	-1.40	-0.55
C382	0.9854	0.9829	0.9921	70HA	-1.46	-1.71	-0.79
C402	0.9834	0.9812	0.9921	70HA	-1.66	-1.88	-0.79
C427	0.9844	0.9819	0.9850	70HA	-1.56	-1.81	-1.50
C440	0.9914	0.9883	0.9952	70HA	-0.86	-1.17	-0.48
C442	0.9801	0.9788	0.9887	70HM	-1.99	-2.12	-1.13
C454	0.9968	0.9924	1.0043	70HA	-0.32	-0.76	0.43
C456	0.9867	0.9841	0.9933	70HA	-1.33	-1.59	-0.67
C458	0.9803	0.9776	0.9920	70HM	-1.97	-2.24	-0.80
C475	0.9905	0.9868	0.9995	70HA	-0.95	-1.32	-0.05
C477	0.9938	0.9895	0.9951	70HA	-0.62	-1.05	-0.49
C494	0.9999	0.9974	1.0115	70HA	-0.01	-0.26	1.15
C496B	1.00017	1.00007	0.9982	70GP	0.17	0.07	-0.18
C499A	0.9854	0.9829	0.9937	70HA	-1.46	-1.71	-0.63
C499B	0.9819	0.9788	0.9895	70HA	-1.81	-2.12	-1.05
C506	0.9910	0.9891	0.9977	70HA	-0.90	-1.09	-0.23
C538	0.9634	0.9665	0.9656	70GX	-3.66	-3.35	-3.44
C541	1.0041	1.0015	1.0043	70GP	0.41	0.15	0.43
C542	0.9992	0.9969	0.9929	70GP	-0.08	-0.31	-0.71
C543	0.9884	0.9861	0.9956	70HA	-1.16	-1.39	-0.44
C546A	0.9922	0.9891	0.9939	70HQ	-0.78	-1.09	-0.61
C546B	0.9736	0.9706	0.9818	70HM	-2.64	-2.94	-1.82
C547	0.9809	0.9784	1.0100	70HQ	-1.91	-2.16	1.00
C548	0.9709	0.9694	0.9714	70SB	-2.91	-3.06	-2.86
C576	0.9768	0.9744	0.9859	70SB	-2.32	-2.56	-1.41
C585	0.9900	0.9872	0.9989	70HA	-1.00	-1.28	-0.11
C600	0.9753	0.9716	0.9716	70GD	-2.47	-2.84	-2.84
C619	0.9943	0.9911	0.9960	70HQ	-0.57	-0.89	-0.40
C620	0.9937	0.9895	0.9954	70HA	-0.63	-1.05	-0.46
C640	1.0023	1.0017	1.0110	70ME	0.23	0.17	1.10
C644	0.0003	0.0003	0.0000	70ME	-9.97	-9.97	*****
C648	0.9968	0.9920	1.0053	70HA	-0.32	-0.80	0.53
C655	0.9934	0.9921	0.9870	70HU	-0.66	-0.79	-1.30
C674	0.9906	0.9880	0.9974	70HF	-0.94	-1.20	-0.26
C677	1.0035	1.0001	1.0173	70SC	0.35	0.01	1.73

LAB CODE	F	SAMPLE D01			SAMPLE D02			DIFFERENCE D02 - D01			INST CODE	LAB
		MEAN X	MEAN Y	MEAN Z	MEAN X	MEAN Y	MEAN Z	ΔX	ΔY	ΔZ		
C646	Ø	54.19X	48.22X	52.18*	53.39X	47.23X	52.06X	-0.80 *	-0.99	-0.11	2.28	70CG C646
C656	Ø	49.56	42.01	51.31	48.59	40.96	51.02	-0.96	-1.05	-0.30	2.39	70SA C656
C657	Ø	49.67	41.85	50.48	48.74	40.85	50.23	-0.93	-1.00	-0.26	2.31	70AC C657
C660	Ø	50.04	42.12	50.57	49.14	41.16	50.37	-0.90	-0.97	-0.20	2.25	70AC C660
C662	Ø	49.58	42.07	50.90	48.87	40.88	50.47	-1.01	-1.19	-0.43	2.65	70DH C662
C664	Ø	49.61	41.86	50.71	48.52	40.67	50.28	-1.09	-1.20	-0.43	2.74	70KC C664
C671A	Ø	49.88	42.19	51.18	48.79	41.01	50.74	-1.09	-1.18	-0.44	2.64	70DH C671A
C671B	Ø	49.92	42.20	50.43	48.84	41.03	50.00	-1.08	-1.17	-0.43	2.62	70DH C671B
C671C	Ø	51.17X	40.39X	50.82	50.05*	39.27X	50.41	-1.11	-1.12	-0.41	2.56	70GC C671C
C671D	Ø	49.07	41.74	50.78	48.03	40.64	50.44	-1.04	-1.10	-0.34	2.45	70HB C671D
C672	Ø	49.78	42.24	51.37	48.68	41.09	50.97	-1.10	-1.15	-0.40	2.49	70GC C672
C675	Ø	49.51	41.96	50.59	48.53	40.89	50.32	-0.98	-1.07	-0.27	2.48	70SA C675
C683	Ø	47.28X	39.45X	48.05X	46.14X	38.24X	47.59X	-1.15	-1.21	-0.46	2.79	70GC C683
C691	Ø	49.51	41.88	50.23	48.47	40.76	49.74	-1.04	-1.12	-0.50	2.48	70SA C691
C699	X	49.62	42.52	51.75	49.00	41.31	51.23	-0.62 X	-1.21	-0.52	5.51X	70BL C699
C700	Ø	49.65	41.98	50.91	48.63	40.87	50.57	-1.02	-1.11	-0.34	2.55	70DH C700
GRAND MEANS		49.58	41.93	50.86	48.57	40.83	50.46	-1.05	-1.14	-0.37	2.63	
SD OF MEANS		.49	.45	.53	.54	.49	.46	.12	.14	.16	.30	
INCLUDED LABS FOR THIS MEAN		67	67	73	69	69	71	71	73	73	74	

LAB CODE	F	SAMPLE D03			SAMPLE D04			DIFFERENCE D04 - D03			INST CODE	LAB
		MEAN X	MEAN Y	MEAN Z	MEAN X	MEAN Y	MEAN Z	ΔX	ΔY	ΔZ		
C646	Ø	9.08	11.83	7.38	8.96*	11.73	7.37	-0.13	-0.10	-0.01	1.28*	70CG C646
C656	Ø	9.61	11.96	7.23	9.36	11.78	7.10	-0.25 *	-0.18	-0.14 X	2.09	70SA C656
C657	Ø	9.61	11.95	7.45	9.53	11.94	7.53	-0.08	-0.01	0.08	1.74	70AC C657
C660	Ø	9.70	12.09	7.40	9.63	12.08	7.51	-0.07	-0.00	0.11	1.84	70AC C660
C662	Ø	9.55	11.99	7.30	9.48	11.98	7.39	-0.07	-0.01	0.09	1.76	70DH C662
C664	Ø	9.58	12.28	7.27	9.56	12.33	7.40	-0.02	0.05	0.13	1.61	70EC C664
C671A	Ø	9.60	12.02	7.38	9.40	11.87	7.37	-0.20	-0.15	-0.02	1.95	70DH C671A
C671B	Ø	9.35	11.86	7.33	9.28	11.85	7.46	-0.07	-0.01	0.13	1.79	70DH C671B
C671C	Ø	9.57	11.40*	6.90	9.41	11.33*	6.91	-0.16	-0.07	0.01	2.22	70GC C671C
C671D	Ø	9.52	11.96	6.91	9.42	11.96	7.02	-0.10	0.00	0.11	2.45*	70HB C671D
C672	Ø	9.78	12.18	7.53	9.78	12.28	7.63	0.00	0.10 *	0.10	1.74	70GC C672
C675	Ø	9.46	11.85	7.27	9.45	11.92	7.41	-0.01	0.07	0.14	1.76	70SA C675
C683	Ø	8.37X	10.79X	6.54*	8.38X	10.88X	6.71*	0.00	0.08	0.18	1.91	70GC C683
C691	Ø	9.76	11.97	7.57	9.68	11.96	7.65	-0.09	-0.02	0.08	1.82	70SA C691
C699	Ø	10.03*	12.48*	7.93*	9.94*	12.46*	8.02*	-0.09	-0.01	0.09	2.00	70BL C699
C700	Ø	9.59	12.67	7.37	9.42	11.94	7.47	-0.17	-0.14	0.10	2.08	70DH C700
GRAND MEANS		9.54	11.96	7.26	9.42	11.90	7.33	-0.11	-0.06	0.07	1.88	
SD OF MEANS		0.23	0.24	0.29	0.23	0.25	0.29	0.07	0.07	0.06	0.22	
INCLUDED LABS FOR THIS MEAN		66	66	68	66	66	68	70	70	69	70	

NOTES ON NBS REFLECTANCE VALUES

The tables on page 23 of this report contain absolute reflectance values measured at 40 wavelengths (380-770 nm) and tristimulus values for three of the five samples covered by this report. The measurements were performed by the Radiometric Physics Division of the National Bureau of Standards.

These values represent state-of-the-art color measurements on a single specimen of each sample. Thus the results give an accurate picture of the values for single specimens and are not an accurate measure of the whole sample population. Participants should be aware of this concept when comparing their measurements to these NBS values.

NBS VALUES FOR SPECTRAL REFLECTANCE

45/0 REFLECTANCE FACTOR

Samples D01, D03, W16

WAVELENGTH (nm)	D01	D03	W16
380	.1224	.0492	.1273
390	.2072	.0524	.2219
400	.3590	.0545	.4387
410	.4595	.0552	.7078
420	.4705	.0556	.8536
430	.4590	.0560	.8899
440	.4513	.0568	.8977
450	.4415	.0580	.9045
460	.4340	.0592	.9090
470	.4317	.0609	.9133
480	.4181	.0632	.9174
490	.3912	.0662	.9205
500	.3743	.0736	.9231
510	.3666	.0972	.9251
520	.3387	.1337	.9271
530	.3064	.1544	.9281
540	.3044	.1569	.9284
550	.3361	.1514	.9288
560	.3636	.1424	.9288
570	.3925	.1318	.9302
580	.4617	.1208	.9315
590	.5493	.1083	.9321
600	.6137	.0949	.9320
610	.6483	.0840	.9314
620	.6637	.0775	.9320
630	.6706	.0739	.9331
640	.6730	.0717	.9337
650	.6736	.0698	.9343
660	.6731	.0689	.9315
670	.6723	.0693	.9249
680	.6708	.0707	.9275
690	.6693	.0727	.9332
700	.6685	.0748	.9353
710	.6678	.0759	.9364
720	.6673	.0750	.9367
730	.6670	.0739	.9367
740	.6661	.0750	.9379
750	.6650	.0780	.9386
760	.6641	.0812	.9400
770	.6634	.0837	.9408

NBS TRISTIMULUS VALUES

45/0 REFLECTANCE FACTOR

SAMPLES D01, D03, W16

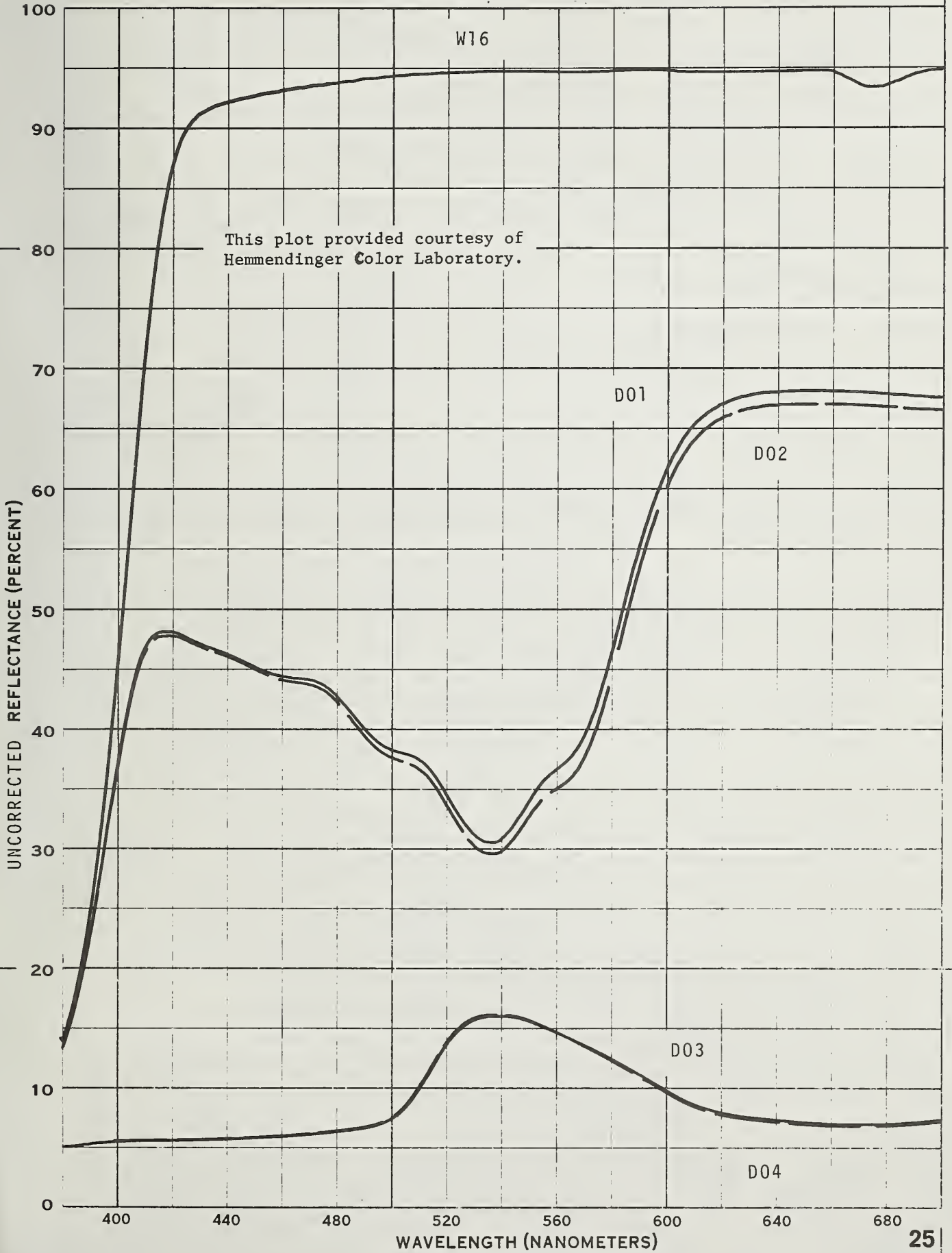
X, Y, Z SPACE

	D01	D03	W16
X	50.54	9.44	90.52
Y	42.69	11.92	92.79
Z	51.51	7.10	106.13

L, a, b SPACE

	D01	D03	W16
L	65.33	34.53	96.33
a	23.75	-11.63	- 0.83
b	- 1.00	11.98	2.13

SPECTROPHOTOMETRIC CURVES OF COLOR AND
COLOR DIFFERENCE NO.27 SAMPLES



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