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CORRELATION STUDIES ON A PROTOTYPE COLOR-MEASUREMENT SYSTEM

BY
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MAY 1983

UNITED STATES ARMY NATICK
RESEARCH & DEVELOPMENT LABORATORIES
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A joint US Army Natick Laboratories-Defense Personnel Support Center prototype color-measuring system, which consists of an Applied Color Systems Spectro Sensor at each installation, was evaluated for individual repeatability and for correlation between the two instruments. The samples (20 fabric swatches, 15 procelain tiles and a color-difference pair) were measured for short-term (10 days) and long-term (5 to 10 weeks) repeatability. Each instrument was found to show a repeatability (as determined by the mean color difference from the mean (MCDM)) of 0.14 color difference units or less for the two time periods studied. The largest color difference observed between the two instruments for these samples was 0.18

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color difference units. Measurement of the color-difference pair, as well as measurements in the infrared region (up to 900 nm), gave similar results. The repeatability exhibited by the two instruments and the correlation of their measurements is considered to be quite good and the system should be suitable for the needs of the Defense Department.

PREFACE

The results reported here are part of Phase III of a project to develop an objective color-measuring system to be used in the procurement of textile fabrics by the Defense Department. This work was presented to the members of the National Research Council Committee on Color Measurement during their September 8 to 9, 1982 meeting at Natick Labs as a preliminary report and addendum. The members of that committee are Dr. David L. MacAdam, Chairman, Dr. Ellen C. Carter, Mr. Franc Grum, Mr. Robert F. Hoban, Dr. Michael E. Breton, and Mr. John J. Hanlon. Mr. Alvin O. Ramsley and Miss Therese R. Commerford were the project officers for this work and the writer would like to thank them and Mr. Kenneth A. Reinhart, Chief, Textile Research and Engineering Division for the support and guidance they provided. The development of this prototype color measurement system was funded through the Materials Testing Technology program.

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CORRELATION STUDIES ON A PROTOTYPE COLOR-MEASUREMENT SYSTEM

INTRODUCTION

Overview of Project

One of the problems the Army faces in the procurement of the millions of yards of textile fabrics it needs each year is the judging of color acceptability. At present, the color is judged by comparing a specimen visually to a standard and several, usually eight, samples that define the thin and full limits. If the color is within the bounds of these limits, it is acceptable. Otherwise it fails. This procedure is not objective and can lead to disagreements in the case of a borderline sample. It is desirable to have a method of measuring the samples in an objective and repeatable way to determine whether or not they meet the Army's requirements.

In recent years, color measuring instruments have become faster and more convenient to use, with good precision and reproducibility. They are all interfaced to computers to do any necessary calculations and are available at a moderate cost. Because of this, the Army has initiated a program to develop and validate an objective color measurement system for the determination of textile color acceptability.[1] This program consists of four phases that are summarized below.

Phase I was a survey of commercial equipment.[2] Three new, relatively inexpensive spectrophotometers were studied to see if they could meet the Army's requirements for reproducibility and accuracy. All three instruments tested, the Macbeth MS–2000, the Diano Match Scan and the Hunter D54–P, were found to be suitable with modifications.

Phase II was the design of the system. Here, the necessary modifications were determined and a detailed specification for procurement of a prototype system written. Also included in this phase was the development of a method for determining the acceptability parameters the computer would need to determine if a sample passed[3] and a fail-safe method of calibration that would allow the instrument to be run only if it is operating correctly.[4]

[1] A.O. Ramsley, T.R. Commerford, and L.B. Hepfinger. Objective Color Measuring System. NATICK/TR–83/005, US Army Natick Research and Development Laboratories, Natick, MA 01760, September 1982, AD A124 505.

[2] F.W. Billmeyer, Jr. and P.J. Alessi. Assessment of color-measuring instruments for objective textile acceptability judgement. NATICK/TR–79/044, US Army Research and Development Command, Natick, MA 01760, March 1979, AD A081 231.

[3] E. Allen and B. Yuhas. Investigation to define acceptability tolerance ranges in various regions of color space. NATICK/TR–80/036, US Army Natick Research and Development Laboratories, Natick, MA 01760, September 1980, AD A094 163.

[4] F.J. Simon and J.H. Lubar. Standardization procedure for two instruments for color measurement. NATICK/TR–82/024, US Army Natick Research and Development Laboratories, Natick, MA 01760, September 1981, AD A116 350.

In Phase III, the prototype instrument was procured and tested. This report details part of the validation studies conducted on the prototype system.

The system will be tried out on an actual procurement in Phase IV. Acceptability will be judged on the trial's results but will be checked by visual observation.

Phase III. The NLABS–DPSC Prototype Color Measurement System

The prototype system that was procured through competitive bidding consists of two Applied Color Systems (ACS) Spectro Sensors, one instrument located at Natick Labs (NLABS) and another at the Defense Personnel Support Center (DPSC) in Philadelphia. The computers that run the two instruments are connected to each other over telephone lines. Because specifications on the color of textiles to be procured and tested at DPSC are determined at NLABS, the two instruments must give the same results when they measure a given sample. They must also agree with themselves and each other over short and long periods of time, so that measurements made next year will be consistent with measurements made this year.

EXPERIMENTAL PROCEDURE

A set of samples were measured on the NLABS instrument and then taken to DPSC to be measured. The samples were:

1. Fifteen 4" x 4" porcelain enamel tiles consisting of five standards (two tan, two green and one blue) with a full and thin limit sample for each standard;

2. Twenty 4" x 10" Nyco twill fabric swatches, 10 tan and 10 green;

3. A pair of tan polyester gelcoat plaques.

Figures 1 through 3 show plots of these samples.

The tile and fabric samples were measured once a day for 10 days for the short-term test and the tiles once a week for 10 weeks for the long-term test. The fabric samples were measured twice a week for five weeks for their long-term test. The tan color difference pair was measured on 10 separate days for three weeks.

The tiles were marked on the back with a circle to ensure that the same area was measured each time and an arrow indicated the up direction. Three readings were taken without moving the sample and an average taken. The textile samples were marked with four circles across their length, with arrows showing the up direction so the twill lines were positioned in a reproducible manner. The samples were backed with a grey tile during measurement and the four readings were averaged. Each half of the tan color difference pair also had a measurement circle marked on the back and each was measured three times and averaged. A grey tile backed up these samples also, because they were slightly translucent.

The samples were measured with a daylight quality source in the specular included, large area of view mode. The 10° 1964 CIE Supplementary Standard Observer and CIE Standard Illuminant D65 were used for all tristimulus value calculations. The CIE 1976 L*a*b* (CIELAB) color space was used for all color difference calculations.

RESULTS AND DISCUSSION

Short-Term Comparison of the Two Instruments

Table 1a, 1b, and 1c contain the results of DPSC's short-term study compared to those of NLABS. In this and following tables, the standard deviations of the tristimulus values and MCDM's (mean color difference from the mean of a set of measurements)[2] are given below the values. For a given sample, the mean value of X for NLABS is compared to the mean value of X for DPSC. If the X values are between one and two standard deviations, they are marked with one asterisk, while two asterisks indicate the means are more than two standard deviations apart. No asterisk indicates the means are within one standard deviation. The Y and Z values are treated the same way. The color difference, ΔE^*, is the CIELAB color difference between the two means.

From Table 1a, 1b, and 1c it can be seen that the MCDM's for DPSC are about the same as those for NLABS, but the tristimulus values are generally higher than Natick's. Many of the measurements on the green fabric samples do not fall within one standard deviation of each other, but are usually within two standard deviations. All of the tan readings are within two standard deviations of each other, and about half are within one. While this makes the means significantly different statistically, the largest ΔE^* that results is only 0.13 CIELAB units. The largest ΔE^* that is observed in data that is within one standard deviation is 0.18 CIELAB units. Because most of the allowable color differences that will be encountered in practice will be much larger than this, it should not cause a problem. The color differences between the NLABS and DPSC means are generally larger than the MCDM's for each instrument's short-term results, ranging from 0.03 to 0.18 CIELAB units, with an average of 0.09 CIELAB units. These results are consistent with an instrument comparison done on the Spectro Sensor several years ago by ACS.[5]

Long-Term Comparison of the Two Instruments

Table 2a, 2b, and 2c contain the long-term results for the two instruments. All of the tile readings are within two standard deviations of each other and color differences between the two sets range from 0.07 to 0.18. The ΔE^*'s in this set are slightly higher than for

[5] R. Stanziola, B. Momiroff, and H. Hemmendinger. The Spectro Sensor – a new generation spectrophotometer. **Color Res. Appl., 4,** 157–163, 1979.

the short-term study, but are still small in practical terms. The fabric samples, which were only measured for five weeks, show smaller color differences between the two sets of data than the tile samples do, but, again, the majority of the green measurements show a statistically significant difference between their means. This, however, results in an acceptably small color difference, as in the short-term results.

Short-Term vs. Long-Term Measurements on each Instrument

Both instruments exhibit good agreement with themselves over a short and long time. Color differences between the sets range from 0.00 to 0.16 CIELAB units, and all but one pair of tristimulus values for each data set are within one standard deviation of each other. These results are given in Tables 3a, 3b, and 3c and 4a, 4b, and 4c.

Measurement of a Tan Color-Difference Pair on each Instrument

The color differences found for the pair of tan polyester gel coat plaques are listed in Table 5. The two instruments show excellent agreement and the means of the ten measurements are within one standard deviation of each other.

Measurements in the Infrared Region

Because some Army fabrics have requirements for reflectance in the infrared, this factor was also investigated. From the data on the tan and green fabric samples, integrated values in the infrared region, up to 900 nm, were obtained. This integration,[6] which is similar to the calculations for Y and L*, in the visible region, is based on the sensitivity of the starlight scope, a nighttime surveillance device. The values Ns and Ls, which are the nighttime equivalents to Y and L* respectively, are calculated for two different illuminants: illumination representing a moonlit sky and a moonless night. The results are shown in Tables 6a and 6b through 9a and 9b.

The intrainstrument comparisons for short- and long-term time periods in Tables 8 and 9 show excellent agreement with only one reading being outside of the one standard deviation limit. The interinstrument comparison in Tables 6a and 6b and 7a and 7b is not as good: most readings are more than one standard deviation from each other and about half are more than two standard deviations apart. As with the visual color differences, these results show a significant statistical difference. These differences, however, are considered small enough in comparison to specification requirements to be acceptable.

[6] A.O. Ramsley and W.G.Y. Yeomans. Psychophysics of Modern Camouflage. Presented at the Army Science Conference, US Military Academy, West Point, NY, 15–18 June 1982.

CONCLUSIONS

Tables 10a through 10d contain a summary of the average MCDM's and color differences for the samples and their standard deviations in the visible region. On the whole, the two instruments show the same degree of repeatability in the visible and near-infrared over the short and long periods of time studied, and show good agreement between themselves. As long as color differences greater than 0.2 CIELAB units are being measured, the agreement between the two instruments should be adequate. Because the color difference between most standards and their limit samples is much larger than this, the new system is suitable for the Army's needs. Long-term studies on both instruments should continue in order to keep a record of the performance of the two instruments and ascertain that they stay in close agreement with each other over a period of years.

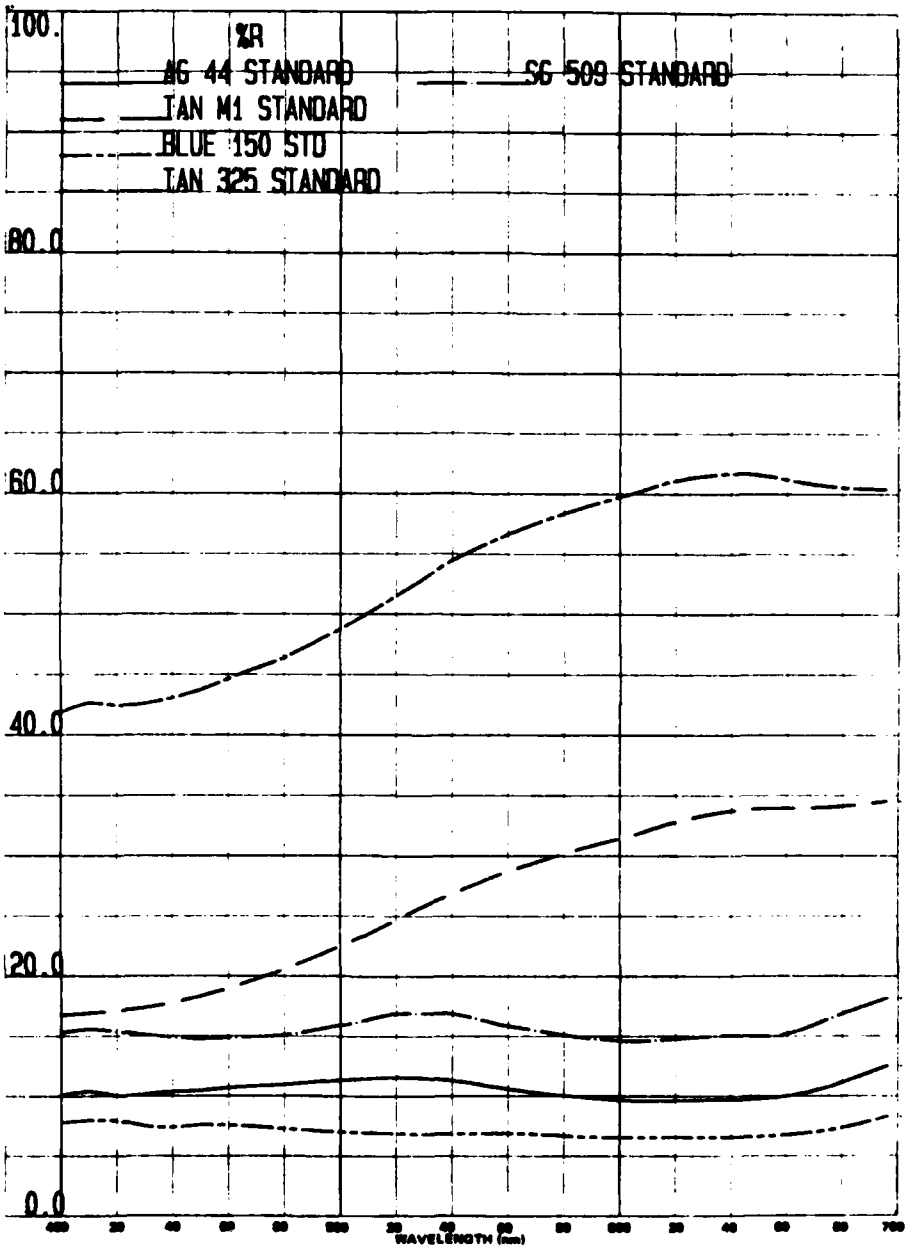

Figure 1. Plot of reflectance vs. wafelength for five tile standards

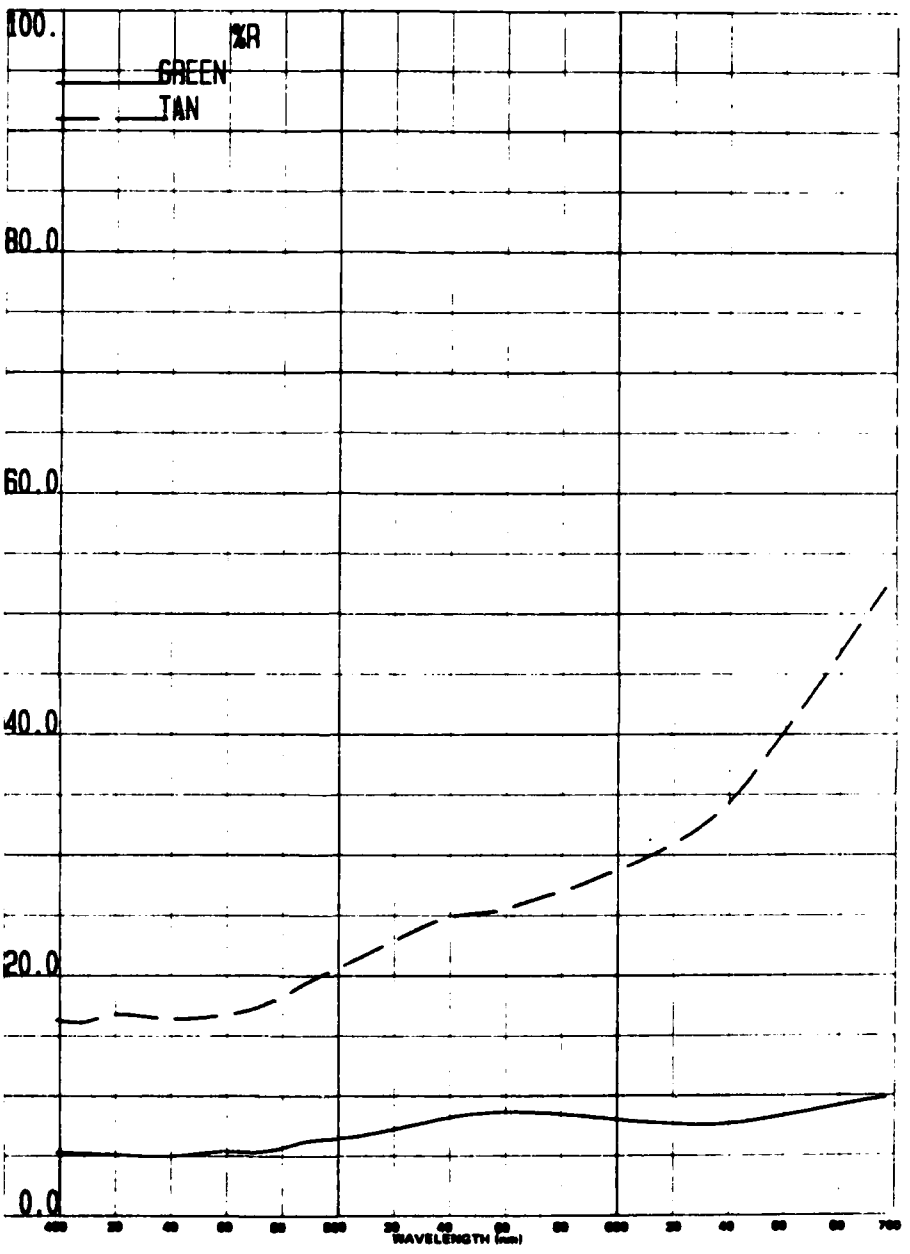

Figure 2. Plot of reflectance vs. wavelength for tan and green fabric samples.

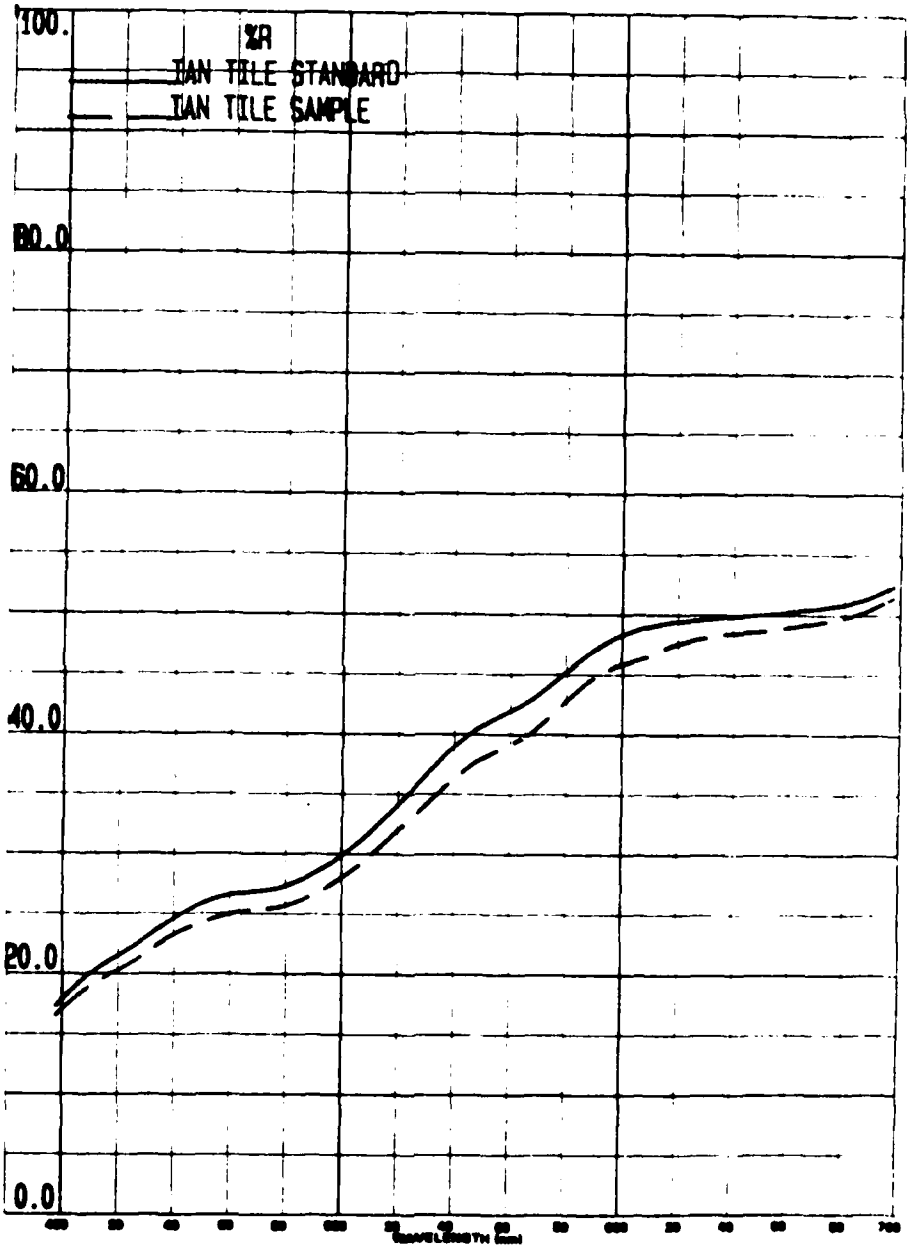

Figure 3. Plot of reflectance vs. wavelength for tan color difference pair

Table 1a. Comparison of Short-Term Repeatability for the Tile Samples between NLABS and DPSC: Standard Deviation of Tristimulus Values (X,Y,Z)

	NLABS				DPSC				
Sample:	X	Y	Z	MCDM	X	Y	Z	MCDM	ΔE*
AG 44									
Standard	9.51	10.53	11.14	.06±	9.54	10.55	11.17	.07±	.10
	±.01	±.02	± .02	.024	±.04	±.04	±.05	.039	
Thin	9.86	10.91	11.51	.07	9.87	10.92	11.53	.07	.03
	.02	.02	.02	.027	.04	.04	.05	.039	
Full	9.24	10.22	10.79	.06	9.27	10.23	10.81	.08	.18
	.01	.02	.02	.031	.04	.04	.05	.044	
Tan MI									
Standard	26.85	27.39	20.36	.03	26.87	27.42	20.42	.06	.08
	.02	.03	.02	.013	.03	.04	.06	.030	
Thin	27.09	27.66	20.87	.03	27.13	27.70	20.93	.06	.06
	.03	.03	.02	.013	.04	.04	.06	.036	
Full	26.28*	26.84*	20.53*	.02	26.33	26.90	20.61	.06	.08
	.02	.02	.02	.017	.04	.04	.06	.036	
Blue 150									
Standard	6.47	6.80	8.09	.03	6.46	6.79	8.07	.09	.04
	.01	.01	.01	.025	.05	.05	.06	.075	
Thin	6.68	7.02	8.32	.02	6.66	7.01	8.29	.09	.13
	.01	.01	.01	.013	.04	.04	.06	.070	
Full	6.30	6.62	7.88	.03	6.29	6.62	7.87	.11	.11
	.00	.00	.01	.022	.04	.05	.07	.061	
Tan 325									
Standard	52.79*	54.62*	47.38*	.04	52.87	54.71	47.52	.04	.10
	.07	.08	.07	.024	.04	.04	.07	.023	
Thin	53.73*	55.61*	47.78*	.03	53.85	55.75	47.95	.07	.12
	.06	.06	.06	.018	.09	.08	.13	.037	
Full	52.16*	53.97*	47.06*	.04	52.26	54.08	47.19	.04	.09
	.06	.07	.08	.021	.04	.03	.07	.023	

Table 1a. Comparison of Short-Term Repeatability for the Tile Samples between NLABS and DPSC: Standard Deviation of Tristimulus Values (X,Y,Z) (cont'd)

	NLABS				DPSC				
Sample:	X	Y	Z	MCDM	X	Y	Z	MCDM	ΔE*
SG 509									
Standard	14.38	15.74	15.99	.04±	14.40	15.76	16.02	.08±	.03
	±.02	±.02	±.02	.019	±.05	±.05	±.08	.048	
Thin	14.79	16.17	16.52	.03	14.84	16.21	16.58	.09	.10
	.01	.02	.02	.015	.07	.07	.11	.075	
Full	14.06	15.41	15.53	.03	14.11	15.47	15.61	.09	.10
	.02	.02	.02	.023	.06	.06	.09	.064	

* = Value between one and two standard deviations from its counterpart.

** = Value more than two standard deviations from its counterpart.

MCDM = Mean color difference from the mean.

ΔE* = CIELAB color difference between the two means.

Table 1b. Comparison of Short-Term Repeatability for the Tan Fabric Samples between NLABS and DPSC

	NLABS				DPSC				
Sample:	X	Y	Z	MCDM	X	Y	Z	MCDM	ΔE*
Tan									
313–488	23.27	23.49	17.56	.03	23.28	23.50	17.58	.03	.03
	.03	.03	.03	.013	.02	.02	.02	.013	
313–332	23.71	23.94	17.93	.04	23.71	23.94	17.95	.03	.04
	.04	.04	.04	.016	.01	.02	.02	.017	
313–321	24.08	24.39	18.40*	.03	24.11	24.42	18.44	.04	.04
	.03	.03	.03	.010	.02	.02	.02	.020	
313–312	23.18*	23.43*	17.59*	.03	23.21	23.47	17.63	.04	.06
	.02	.02	.02	.011	.02	.02	.03	.021	
313–319	23.40	23.66	17.79	.04	23.42	23.69	17.82	.04	.05
	.03	.03	.03	.017	.03	.03	.03	.014	
313–640	23.67	23.86	17.78*	.04	23.69	23.89	17.82	.03	.06
	.03	.03	.03	.014	.02	.02	.03	.020	
511–036	24.35	24.58	18.06	.03	24.38	24.61	18.09	.04	.03
	.03	.03	.03	.015	.02	.02	.03	.012	
511–123	24.09*	24.33*	17.98*	.04	24.13	24.38	18.03	.05	.06
	.03	.03	.03	.014	.03	.03	.04	.019	
511–167	24.74*	25.00*	18.45*	.05	24.79	25.06	18.51	.05	.07
	.03	.04	.04	.021	.03	.03	.05	.024	
519–078	23.34*	23.57*	17.24*	.07	23.42	23.66	17.35	.04	.12
	.06	.06	.06	.034	.03	.03	.04	.028	

Table 1c. Comparison of Short-Term Repeatability for the Green Fabric Samples between NLABS and DPSC

Sample:	NLABS X	NLABS Y	NLABS Z	NLABS MCDM	DPSC X	DPSC Y	DPSC Z	DPSC MCDM	ΔE*
Green									
600–0058	6.74	7.19*	5.33*	.05	6.78	7.23	5.37	.06	.10
	.02	.01	.01	.031	.02	.02	.02	.016	
600–057	6.98	7.42	5.48	.06	7.00	7.44	5.50	.06	.05
	.01	.01	.01	.036	.02	.02	.02	.014	
925–622	6.98*	7.48	5.58	.03	7.00	7.50	5.59	.14	.05
	.01	.01	.01	.011	.01	.03	.02	.182	
925–618	6.88*	7.38*	5.48*	.03	6.92	7.42	5.51	.07	.09
	.01	.01	.01	.024	.02	.02	.02	.035	
925–617	6.95*	7.45*	5.54*	.05	6.99	7.49	5.57	.08	.09
	.01	.01	.01	.033	.02	.02	.02	.026	
925–614	7.15**	7.66**	5.66**	.03	7.18	7.70	5.68	.06	.13
	.01	.00	.01	.022	.01	.01	.01	.013	
925–613	7.22*	7.74*	5.80	.05	7.24	7.76	5.81	.06	.05
	.01	.01	.01	.022	.01	.01	.01	.015	
925–606	7.36*	7.90*	5.92	.07	7.39	7.93	5.94	.05	.07
	.02	.02	.01	.034	.01	.01	.02	.038	
925–608	7.41**	7.94**	5.96	.05	7.44	7.98	5.99	.04	.11
	.01	.01	.01	.034	.01	.01	.02	.027	
925–601	7.40*	7.94*	5.95	.06	7.43	7.97	5.97	.06	.07
	.02	.02	.02	.040	.02	.02	.02	.023	

Table 2a. Comparison of Long-Term Repeatability for the Tile Samples between NLABS and DPSC: Standard Deviation of Tristimulus Values (X,Y,Z)

	NLABS				DPSC				
Sample:	**X**	**Y**	**Z**	**MCDM**	**X**	**Y**	**Z**	**MCDM**	**ΔE***
AG44									
Standard	9.51*	10.52*	11.12*	.06	9.55	10.56	11.19	.06	.11
	.02	.02	.02	.020	.03	.03	.05	.042	
Thin	9.85	10.90	11.49*	.06	9.88	10.93	11.54	.06	.07
	.02	.03	.03	.011	.03	.03	.05	.038	
Full	9.23*	10.20*	10.77	.05	9.28	10.25	10.83	.09	.10
	.02	.02	.02	.025	.04	.03	.06	.051	
Tan MI									
Standard	26.84	27.38*	20.35*	.03	26.88	27.43	20.44	.06	.11
	.03	.03	.03	.018	.04	.03	.06	.033	
Thin	27.09	27.66*	20.86	.03	27.13	27.70	20.95	.06	.11
	.03	.02	.02	.018	.04	.03	.06	.038	
Full	26.28*	26.84*	20.52*	.03	26.34	26.91	20.64	.06	.13
	.03	.03	.02	.016	.04	.04	.07	.039	
Blue 150									
Standard	6.46	6.79	8.07	.04	6.49	6.81	8.11	.13	.14
	.02	.02	.02	.018	.05	.05	.08	.070	
Thin	6.66	7.01	8.29	.05	6.70	7.04	8.35	.13	.16
	.02	.02	.02	.021	.06	.05	.08	.070	
Full	6.29	6.61	7.86	.04	6.33	6.66	7.93	.15	.15
	.02	.01	.02	.032	.06	.06	.09	.073	
Tan 325									
Standard	52.79*	54.62*	47.38*	.04	52.89	54.73	47.56	.05	.11
	.07	.08	.07	.024	.05	.06	.11	.031	
Thin	53.73*	55.61*	47.77*	.04	53.85	55.74	47.95	.06	.10
	.07	.07	.08	.020	.06	.06	.11	.032	
Full	52.17*	53.98*	47.06*	.04	52.29	54.11	47.24	.06	.10
	.07	.08	.08	.020	.06	.06	.11	.033	

Table 2a. Comparison of Long-Term Repeatability for the Tile Samples between NLABS and DPSC: Standard Deviation of Tristimulus Values (X,Y,Z) (cont'd)

	NLABS				DPSC				
Sample:	**X**	**Y**	**Z**	**MCDM**	**X**	**Y**	**Z**	**MCDM**	**ΔE***
SG509									
Standard	14.37	15.73	15.98	.04	14.44	15.80	16.09	.11	.13
	.02	.02	.03	.012	.07	.07	.11	.069	
Thin	14.78*	16.15*	16.50*	.04	14.86	16.24	16.62	.11	.13
	.03	.03	.04	.031	.07	.07	.11	.068	
Full	14.04*	15.40*	15.51*	.06	14.13	15.48	15.64	.11	.18
	.03	.04	.04	.034	.07	.07	.11	.070	

* = Value between one and two standard deviations from its counterpart.
** = Value more than two standard deviations from its counterpart.
MCDM = Mean color difference from the mean.
ΔE* = CIELAB color difference between the two means.

Table 2b. Comparison of Long-Term Repeatability for the Tan Fabric Samples between NLABS and DPSC

	NLABS				DPSC				
Sample:	X	Y	Z	MCDM	X	Y	Z	MCDM	ΔE*
Tans									
313–488	23.27	23.49	17.56	.04	23.28	23.51	17.58	.03	.05
	.02	.03	.02	.008	.03	.03	.03	.018	
313–332	23.72	23.94	17.94	.04	23.73	23.96	17.96	.03	.05
	.04	.04	.03	.019	.03	.03	.03	.022	
313–321	24.09	24.39	18.40	.04	24.10	24.41	18.43	.04	.05
	.03	.03	.03	.012	.03	.03	.03	.018	
313–312	23.18	23.43	17.60	.04	23.20	23.46	17.63	.03	.05
	.02	.02	.02	.011	.02	.03	.03	.016	
313–319	23.40	23.67	17.79	.04	23.41	23.69	17.82	.04	.05
	.03	.04	.03	.018	.02	.02	.03	.011	
313–640	23.68	23.86	17.79*	.03	23.69	23.89	17.83	.04	.10
	.03	.04	.03	.018	.03	.03	.03	.019	
511–036	24.35*	24.59	18.07	.04	24.39	24.63	18.10	.04	.04
	.03	.04	.03	.020	.02	.03	.03	.013	
511–123	24.09	24.33*	17.98*	.05	24.13	24.38	18.03	.04	.06
	.04	.04	.04	.019	.03	.03	.04	.015	
511–167	24.75*	25.01*	18.46*	.05	24.81	25.08	18.52	.05	.08
	.04	.05	.04	.020	.03	.03	.04	.021	
519–078	23.35*	25.58**	17.26**	.07	23.45	23.69	17.37	.04	.12
	.07	.02	.04	.037	.03	.03	.04	.027	

Table 2c. Comparison of Long-Term Repeatability for the Green Fabric Samples between NLABS and DPSC

	NLABS				DPSC				
Sample:	X	Y	Z	MCDM	X	Y	Z	MCDM	ΔE*
Greens									
600–058	6.74*	7.20*	5.33*	.06	6.78	7.24	5.37	.06	.10
	.02	.02	.02	.028	.01	.01	.02	.021	
600–057	6.99	7.43*	5.48*	.08	7.01	7.46	5.51	.07	.11
	.02	.02	.01	.024	.02	.02	.02	.039	
925–622	6.99*	7.49**	5.58**	.06	7.01	7.52	5.61	.06	.11
	.01	.01	.01	.021	.01	.01	.01	.016	
925–618	6.89*	7.39*	5.48*	.06	6.93	7.43	5.52	.06	.10
	.02	.02	.01	.016	.02	.02	.02	.017	
925–617	6.96**	7.46**	5.54**	.06	7.01	7.51	5.59	.07	.12
	.02	.02	.01	.031	.02	.02	.02	.039	
925–614	7.16**	7.67**	5.66*	.05	7.19	7.70	5.68	.06	.07
	.01	.01	.01	.025	.01	.01	.01	.018	
925–613	7.22**	7.74**	5.80*	.07	7.25	7.78	5.82	.05	.13
	.01	.01	.01	.013	.01	.01	.01	.022	
925–606	7.37**	7.91**	5.92*	.07	7.40	7.94	5.95	.07	.07
	.01	.01	.01	.028	.01	.01	.02	.051	
925–608	7.41**	7.95**	5.96*	.05	7.45	7.99	6.00	.05	.09
	.01	.01	.01	.019	.01	.01	.02	.026	
925–601	7.40*	7.93**	5.94*	.05	7.44	7.98	5.98	.07	.12
	.01	.01	.01	.014	.02	.02	.02	.042	

Table 3a. Comparison of Short- and Long-Term Repeatability for the Tile Samples on the NLABS Spectro Sensor: Standard Deviation of Tristimulus Values (X,Y,Z)

	Short Term				Long Term				
Sample:	X	Y	Z	MCDM	X	Y	Z	MCDM	ΔE*
AG 44									
Standard	9.51	10.53	11.14	.06	9.51	10.52	11.12	.06	.08
	.01	.02	.02	.024	.02	.02	.02	.020	
Thin	9.86	10.91	11.51	.07	9.85	10.90	11.49	.06	.03
	.02	.02	.02	.027	.02	.03	.03	.011	
Full	9.24	10.22	10.79	.06	9.23	10.20	10.77	.05	.08
	.01	.02	.02	.031	.02	.02	.02	.025	
Tan M1									
Standard	26.85	27.39	20.36	.03	26.84	27.38	20.35	.03	.01
	.02	.03	.02	.013	.03	.03	.03	.018	
Thin	27.09	27.66	20.87	.03	27.09	27.66	20.86	.03	.02
	.03	.03	.02	.013	.03	.02	.02	.018	
Full	26.28	26.84	20.53	.02	26.28	26.84	20.52	.03	.02
	.02	.02	.02	.017	.03	.03	.02	.016	
Blue 150									
Standard	6.47	6.80	8.09	.03	6.46	6.79	8.07	.04	.04
	.01	.01	.01	.025	.02	.02	.02	.018	
Thin	6.68	7.02	8.32*	.02	6.66	7.01	8.29	.05	.13
	.01	.01	.01	.013	.02	.02	.02	.021	
Full	6.30	6.62	7.88	.03	6.29	6.61	7.86	.04	.04
	.00	.00	.01	.022	.02	.01	.02	.032	
Tan 325									
Standard	52.79	54.62	47.38	.04	52.79	54.62	47.38	.04	.00
	.07	.08	.07	.024	.07	.08	.07	.024	
Thin	53.73	55.61	47.78	.03	53.73	55.61	47.77	.04	.01
	.06	.06	.06	.018	.07	.07	.08	.020	

Table 3a. Comparison of Short- and Long-Term Repeatability for the Tile Samples on the NLABS Spectro Sensor: Standard Deviation of Tristimulus Values (X,Y,Z) (cont'd)

	Short Term				Long Term				
Sample:	X	Y	Z	MCDM	X	Y	Z	MCDM	ΔE*
Full	52.16	53.97	47.06	.04	52.17	53.98	47.06	.04	.01
	.06	.07	.08	.021	.07	.08	.08	.020	
SG 509									
Standard	14.38	15.74	15.99	.04	14.37	15.73	15.98	.04	.01
	.02	.02	.02	.019	.02	.02	.03	.012	
Thin	14.79	16.17	16.52	.03	14.78	16.15	16.50	.04	.06
	.01	.02	.02	.015	.03	.03	.04	.031	
Full	14.06	15.41	15.53	.03	14.04	15.40	15.51	.06	.07
	.02	.02	.02	.023	.03	.04	.04	.034	

* = Value between one and two standard deviations from its counterpart.
** = Value more than two standard deviations from its counterpart.
MCDM = Mean color difference from the mean.
ΔE* = CIELAB color difference between the two means.

Table 3b. Comparison of Short- and Long-Term Repeatability for the Tan Fabric Samples on the NLABS Spectro Sensor

	Short Term				Long Term				
Sample:	X	Y	Z	MCDM	X	Y	Z	MCDM	ΔE*
Tans									
313–488	23.27	23.49	17.56	.03	23.27	23.49	17.56	.04	.00
	.03	.03	.03	.013	.02	.03	.02	.008	
313–332	23.71	23.94	17.93	.04	23.72	23.94	17.94	.04	.05
	.04	.04	.04	.016	.04	.04	.03	.019	
313–321	24.08	24.39	18.40	.03	24.09	24.39	18.40	.04	.04
	.03	.03	.03	.010	.03	.03	.03	.012	
313–312	23.18	23.43	17.59	.03	23.18	23.43	17.60	.04	.02
	.02	.02	.02	.011	.02	.02	.02	.011	
313–319	23.40	23.66	17.79	.04	23.40	23.67	17.79	.04	.05
	.03	.03	.03	.017	.03	.04	.03	.018	
313–640	23.67	23.86	17.78	.04	23.68	23.86	17.79	.03	.05
	.03	.03	.03	.014	.03	.04	.03	.018	
511–036	24.35	24.58	18.06	.03	24.35	24.59	18.07	.04	.04
	.03	.03	.03	.015	.03	.04	.03	.020	
511–123	24.09	24.33	17.98	.04	24.09	24.33	17.98	.05	.00
	.03	.03	.03	.014	.04	.04	.04	.019	
511–167	24.74	25.00	18.45	.05	24.75	25.01	18.46	.05	.01
	.03	.04	.04	.021	.04	.05	.04	.020	
519–078	23.34	23.57	17.24	.07	23.35	23.58	17.26	.07	.03
	.06	.06	.06	.034	.07	.02	.04	.037	

Table 3c. Comparison of Short- and Long-Term Repeatability for the Green Fabric Samples on the NLABS Spectro Sensor

	Short Term				Long Term				
Sample:	X	Y	Z	MCDM	X	Y	Z	MCDM	ΔE*
Green									
600-0058	6.74	7.19	5.33	.05	6.74	7.20	5.33	.06	.11
	.02	.01	.01	.031	.02	.02	.02	.028	
600–057	6.98	7.42	5.48	.06	6.99	7.43	5.48	.08	.04
	.01	.01	.01	.036	.02	.02	.01	.024	
925–622	6.98	7.48	5.58	.03	6.99	7.49	5.58	.06	.04
	.01	.01	.01	.011	.01	.01	.01	.021	
925–618	6.88	7.38	5.48	.03	6.89	7.39	5.48	.06	.04
	.01	.01	.01	.024	.02	.02	.01	.016	
925–617	6.95	7.45	5.54	.05	6.96	7.46	5.54	.06	.04
	.01	.01	.01	.033	.02	.02	.01	.031	
925–614	7.15	7.66	5.66	.03	7.16	7.67	5.66	.05	.04
	.01	.00	.01	.022	.01	.01	.01	.025	
925–613	7.22	7.74	5.80	.05	7.22	7.74	5.80	.07	.00
	.01	.01	.01	.022	.01	.01	.01	.013	
925–606	7.36	7.90	5.92	.07	7.37	7.91	5.92	.07	.04
	.02	.02	.01	.034	.01	.01	.01	.028	
925–608	7.41	7.94	5.96	.05	7.41	7.95	5.96	.05	.10
	.01	.01	.01	.034	.01	.01	.01	.019	
925–601	7.40	7.94	5.95	.06	7.40	7.93	5.94	.05	.09
	.02	.02	.02	.040	.01	.01	.01	.014	

Table 4a. Comparison of Short- and Long-Term Repeatability for the Tile Samples on the DPSC Spectro Sensor: Standard Deviation of Tristimulus Values (X,Y,Z)

	Short Term				Long Term				
Sample:	X	Y	Z	MCDM	X	Y	Z	MCDM	ΔE*
AG 44									
Standard	9.54	10.55	11.17	.07	9.55	10.56	11.19	.06	.03
	.04	.04	.05	.039	.03	.03	.05	.042	
Thin	9.87	10.92	11.53	.07	9.88	10.93	11.54	.06	.02
	.04	.04	.05	.039	.03	.03	.05	.038	
Full	9.27	10.23	10.81	.08	9.28	10.25	10.83	.09	.08
	.04	.04	.05	.044	.04	.03	.06	.051	
Tan M1									
Standard	26.87	27.42	20.42	.06	26.88	27.43	20.44	.06	.02
	.03	.04	.06	.030	.04	.03	.06	.033	
Thin	27.13	27.70	20.93	.06	27.13	27.70	20.95	.06	.04
	.04	.04	.06	.036	.04	.03	.06	.038	
Full	26.33	26.90	20.61	.06	26.34	26.91	20.64	.06	.04
	.04	.04	.06	.036	.04	.04	.07	.039	
Blue 150									
Standard	6.46	6.79	8.07	.09	6.49	6.81	8.11	.13	.14
	.05	.05	.06	.075	.05	.05	.08	.070	
Thin	6.66	7.01	8.29	.09	6.70	7.04	8.35	.13	.16
	.04	.04	.06	.070	.06	.05	.08	.070	
Full	6.29	6.62	7.87	.11	6.33	6.66	7.93	.15	.11
	.04	.05	.07	.061	.06	.06	.09	.073	
Tan 325									
Standard	52.87	54.71	47.52	.04	52.89	54.73	47.56	.05	.03
	.04	.04	.07	.023	.05	.06	.11	.031	
Thin	53.85	55.75	47.95	.07	53.85	55.74	47.95	.06	.03
	.09	.08	.13	.037	.06	.06	.11	.032	

Table 4a. Comparison of Short- and Long-Term Repeatability for the Tile Samples on the DPSC Spectro Sensor: Standard Deviation of Tristimulus Values (X,Y,Z) (cont'd)

	Short Term				Long Term				
Sample:	X	Y	Z	MCDM	X	Y	Z	MCDM	ΔE*
Full	52.26	54.08	47.19	.04	52.29	54.11	47.24	.06	.03
	.04	.03	.07	.023	.06	.06	.11	.033	
SG 509									
Standard	14.40	15.76	16.02	.08	14.44	15.80	16.09	.11	.08
	.05	.05	.08	.048	.07	.07	.11	.069	
Thin	14.84	16.21	16.58	.09	14.86	16.24	16.62	.11	.06
	.07	.07	.11	.075	.07	.07	.11	.068	
Full	14.11	15.47	15.61	.09	14.13	15.48	15.64	.11	.08
	.06	.06	.09	.064	.07	.07	.11	.070	

* = Value between one and two standard deviations from its counterpart.
** = Value more than two standard deviations from its counterpart.
MCDM = Mean color difference from the mean.
ΔE* = CIELAB color difference between the two means.

Table 4b. Comparison of Short- and Long-Term Repeatability for the Tan Fabric Samples on the DPSC Spectro Sensor

	Short Term				Long Term				
Sample:	X	Y	Z	MCDM	X	Y	Z	MCDM	ΔE*
Tans									
313–488	23.28	23.50	17.58	.03	23.28	23.51	17.58	.03	.05
	.02	.02	.02	.013	.03	.03	.03	.018	
313–332	23.71	23.94	17.95	.03	23.73	23.96	17.96	.03	.02
	.01	.02	.02	.017	.03	.03	.03	.022	
313–321	24.11	24.42	18.44	.04	24.10	24.41	18.43	.04	.01
	.02	.02	.02	.020	.03	.03	.03	.018	
313–312	23.21	23.47	17.63	.04	23.20	23.46	17.63	.03	.02
	.02	.02	.03	.021	.02	.03	.03	.016	
313–319	23.42	23.69	17.82	.04	23.41	23.69	17.82	.04	.04
	.03	.03	.03	.014	.02	.02	.03	.011	
313–640	23.69	23.89	17.82	.03	23.69	23.89	17.83	.04	.02
	.02	.02	.03	.020	.03	.03	.03	.019	
511–036	24.38	24.61	18.09	.04	24.39	24.63	18.10	.04	.05
	.02	.02	.03	.012	.02	.03	.03	.013	
511–123	24.13	24.38	18.03	.05	24.13	24.38	18.03	.04	.00
	.03	.03	.04	.019	.03	.03	.04	.015	
511–167	24.79	25.06	18.51	.05	24.81	25.08	18.52	.05	.02
	.03	.03	.05	.024	.03	.03	.04	.021	
519–078	23.42	23.66	17.35	.04	23.45	23.69	17.37	.04	.03
	.03	.03	.04	.028	.03	.03	.04	.027	

Table 4c. Comparison of Short- and Long-Term Repeatability for the Green Fabric Samples on the DPSC Spectro Sensor

	Short Term				Long Term				
Sample:	X	Y	Z	MCDM	X	Y	Z	MCDM	ΔE*
Greens									
600–0058	6.78	7.23	5.37	.06	6.78	7.24	5.37	.06	.11
	.02	.02	.02	.016	.01	.01	.02	.021	
600–057	7.00	7.44	5.50	.06	7.01	7.46	5.51	.07	.10
	.02	.02	.02	.014	.02	.02	.02	.039	
925–622	7.00	7.50	5.59	.14	7.01	7.52	5.61	.06	.10
	.01	.03	.02	.182	.01	.01	.01	.016	
925–618	6.92	7.42	5.51	.07	6.93	7.43	5.52	.06	.02
	.02	.02	.02	.035	.02	.02	.02	.017	
925–617	6.99	7.49	5.57	.08	7.01	7.51	5.59	.07	.05
	.02	.02	.02	.026	.02	.02	.02	.039	
925–614	7.18	7.70	5.68	.06	7.19	7.70	5.68	.06	.10
	.01	.01	.01	.013	.01	.01	.01	.018	
925–613	7.24	7.76*	5.81	.06	7.25	7.78	5.82	.05	.10
	.01	.01	.01	.015	.01	.01	.01	.022	
925–606	7.39	7.93	5.94	.05	7.40	7.94	5.95	.07	.02
	.01	.01	.02	.038	.01	.01	.02	.051	
925–608	7.44	7.98	5.99	.04	7.45	7.99	6.00	.05	.02
	.01	.01	.02	.027	.01	.01	.02	.036	
925–601	7.43	7.97	5.97	.06	7.44	7.98	5.98	.07	.02
	.02	.02	.02	.023	.02	.02	.02	.042	

Table 5. CIELAB Color Differences for Tan Color Difference Pair

Observation	NLABS	DPSC
1	1.95	1.93
2	1.96	1.97
3	1.94	1.92
4	1.95	1.93
5	1.93	1.92
6	1.94	1.93
7	1.94	1.95
8	1.95	1.92
9	1.95	1.94
10	1.96	1.93
Average	1.95 ±.009	1.94 ±.016

Table 6a. Comparison of Short-Term Infrared Repeatability for the Tan Fabric Samples between NLABS and DPSC: Standard Deviation of Starlight Scope Values (Ns,Ls)

	NLABS				DPSC			
	Moonlit		Moonless		Moonlit		Moonless	
Sample:	Ns	Ls	Ns	Ls	Ns	Ls	Ns	Ls
Tans								
313–488	35.38*	66.04	35.28*	65.97	35.40	66.06	35.31	65.99
	.01	.02	.02	.03	.01	.02	.01	.02
313–332	35.59	66.21	35.54	66.17	35.60	66.21	35.56	66.19
	.03	.02	.03	.03	.03	.02	.03	.03
313–321	36.10*	66.60*	36.03*	66.54*	36.14	66.63	36.08	66.58
	.01	.01	.02	.01	.03	.02	.03	.02
313–312	35.21*	65.91*	35.12	65.84	35.26	65.96	35.18	65.89
	.02	.02	.02	.02	.03	.02	.03	.03
313–319	35.39*	66.05	35.31*	65.99	35.43	66.08	35.36	66.02
	.02	.03	.03	.04	.03	.03	.03	.02
313–640	35.60*	66.22	35.56*	66.18	35.64	66.24	35.61	66.22
	.03	.02	.03	.04	.03	.03	.03	.02
511–036	36.60*	66.98	36.59*	66.97	36.65	67.01	36.65	67.01
	.03	.03	.03	.03	.02	.02	.02	.03
511–123	35.65	66.25	35.71*	66.29*	35.71	66.29	35.77	66.34
	.06	.05	.05	.04	.04	.02	.04	.03
511–167	36.67*	67.03*	36.70*	67.06*	36.74	67.08	36.79	67.12
	.04	.02	.04	.03	.04	.03	.04	.03
519–078	35.55**	66.18*	35.53*	66.16*	35.65	66.25	35.63	66.24
	.05	.04	.05	.04	.04	.03	.04	.03

Table 6b. Comparison of Stort-Term Infrared Repeatability for the Green Fabric Samples between NLABS and DPSC

	NLABS				DPSC			
	Moonlit		Moonless		Moonlit		Moonless	
Sample:	Ns	Ls	Ns	Ls	Ns	Ls	Ns	Ls
Greens								
600–0058	8.12**	34.24**	8.39**	34.78**	8.19	34.37	8.45	34.91
	.02	.03	.02	.03	.01	.03	.02	.03
600–057	8.39**	34.79**	8.68**	35.35**	8.44	34.87	8.72	35.43
	.02	.03	.02	.03	.01	.03	.01	.03
925–622	8.49**	34.99**	8.74**	35.48**	8.54	35.09	8.79	35.58
	.01	.01	.01	.01	.01	.02	.01	.02
925–618	8.30**	34.60**	8.55**	35.11**	8.37	34.74	8.62	35.24
	.01	.02	.01	.02	.02	.04	.02	.04
925–617	8.40**	34.81**	8.65**	35.31**	8.47	34.94	8.72	35.44
	.01	.02	.01	.02	.02	.04	.02	.03
925–614	8.70**	35.41**	8.96**	35.90**	8.76	35.52	9.02	36.02
	.01	.01	.01	.01	.01	.02	.01	.02
925–613	8.82**	35.64**	9.06**	36.10**	8.87	35.73	9.11	36.20
	.01	.01	.01	.01	.02	.03	.02	.03
925–606	8.99**	35.97**	9.24**	36.45**	9.05	36.08	9.30	36.55
	.01	.02	.01	.03	.01	.03	.01	.03
925–608	9.01**	36.01**	9.26**	36.49**	9.07	36.12	9.33	36.60
	.01	.02	.01	.02	.02	.03	.01	.03
925–601	9.06**	36.11**	9.31**	36.58**	9.12	36.22	9.37	36.68
	.02	.03	.02	.04	.02	.03	.02	.03

Table 7a. Comparison of Long-Term Infrared Repeatability for the Tan Fabric Samples between NLABS and DPSC: Standard Deviation of Starlight Scope Values (Ns,Ls)

	NLABS				DPSC			
	Moonlit		Moonless		Moonlit		Moonless	
Sample:	Ns	Ls	Ns	Ls	Ns	Ls	Ns	Ls
Tans								
313–488	35.37	66.03	35.28	65.96*	35.39	66.05	35.30	65.99
	.02	.02	.03	.02	.03	.02	.03	.02
313–332	35.59	66.20	35.54	66.17	35.61	66.22	35.58	66.20
	.04	.03	.04	.04	.03	.02	.03	.02
313–321	36.10	66.60	36.03	66.54*	36.13	66.62	36.07	66.57
	.02	.01	.01	.01	.03	.04	.04	.02
313–312	35.22*	65.92	35.13*	65.85*	35.26	65.95	35.17	65.89
	.02	.02	.02	.02	.03	.03	.03	.03
313–319	35.40	66.06	35.31*	65.99	35.43	66.08	35.35	66.02
	.03	.03	.03	.03	.03	.02	.02	.03
313–640	35.60	66.22	35.56	66.19	35.64	66.24	35.60	66.22
	.03	.03	.03	.02	.04	.03	.04	.03
511–036	36.60*	66.97*	36.59**	66.97*	36.66	67.03	36.66	67.02
	.03	.03	.03	.03	.03	.03	.03	.03
511–123	35.64*	66.24*	35.69*	66.29*	35.71	66.30	35.77	66.35
	.03	.03	.03	.03	.04	.03	.04	.03
511–167	36.68**	67.03**	36.71**	67.06**	36.77	67.10	36.81	67.13
	.04	.02	.04	.03	.04	.03	.04	.03
519–078	35.56**	66.18**	35.53*	66.16*	34.67	66.27	35.65	66.25
	.05	.03	.06	.05	.04	.03	.04	.04

Table 7b. Comparison of Long-Term Infrared Repeatability for the Green Fabric Samples between NLABS and DPSC

	NLABS				DPSC			
	Moonlit		Moonless		Moonlit		Moonless	
Sample:	Ns	Ls	Ns	Ls	Ns	Ls	Ns	Ls
Green								
600–0058	8.13*	34.26**	8.40*	34.80**	8.19	34.38	8.46	34.92
	.03	.05	.03	.05	.01	.04	.02	.03
600–057	8.40**	34.80**	8.68**	35.37*	8.45	34.90	8.73	35.45
	.02	.04	.02	.05	.02	.04	.02	.04
925–622	8.50**	35.02**	8.75**	35.50**	8.55	35.11	8.80	35.59
	.02	.03	.01	.03	.01	.02	.01	.02
925–618	8.31**	34.62**	8.56**	35.13**	8.38	34.76	8.63	35.26
	.02	.04	.02	.04	.02	.05	.02	.05
925–617	8.42**	34.84**	8.67**	35.34**	8.49	34.98	8.74	35.48
	.03	.05	.03	.05	.02	.04	.02	.03
925–614	8.71**	35.42**	8.97**	35.92**	8.76	35.52	9.02	36.02
	.02	.03	.02	.03	.01	.02	.01	.02
925–613	8.83**	35.65**	9.07**	36.12**	8.88	35.75	9.12	3 6.22
	.02	.03	.02	.03	.01	.02	.01	.03
925–606	9.00**	35.99**	9.25**	36.47**	9.06	36.09	9.31	36.57
	.02	.04	.02	.03	.01	.02	.02	.02
925–608	9.02**	36.02**	9.27**	36.50**	9.08	36.14	9.33	36.62
	.02	.03	.02	.03	.02	.03	.02	.03
925–601	9.06**	36.11**	9.31**	36.57**	9.13	36.24	9.38	36.70
	.02	.03	.02	.03	.02	.04	.02	.04

Table 8a. Comparison of the Short- and Long-Term Infrared Repeatability for the Tan Fabric Samples on the NLABS Spectro Sensor: Standard Deviation of Starlight Scope Values (Ns,Ls)

	Short				Long			
	Moonlit		Moonless		Moonlit		Moonless	
Sample:	Ns	Ls	Ns	Ls	Ns	Ls	Ns	Ls
Tans								
313–488	35.38	66.04	35.28	65.97	35.37	66.03	35.28	65.96
	.01	.02	.02	.03	.02	.02	.03	.02
313–332	35.59	66.21	35.54	66.17	35.59	66.20	35.54	66.17
	.03	.02	.03	.03	.04	.03	.04	.04
313–321	36.10	66.60	36.03	66.54	36.10	66.60	36.03	66.54
	.01	.01	.02	.01	.02	.01	.01	.01
313–312	35.21	65.91	35.12	65.84	35.22	65.92	35.13	65.85
	.02	.02	.02	.02	.02	.02	.02	.02
313–319	35.39	66.05	35.31	65.99	35.40	66.06	35.31	65.99
	.02	.03	.03	.04	.03	.03	.03	.03
313–640	35.60	66.22	35.56	66.18	35.60	66.22	35.56	66.19
	.03	.02	.03	.04	.03	.03	.03	.02
511–036	36.60	66.98	36.59	66.97	36.60	66.97	36.59	66.97
	.03	.03	.03	.03	.03	.03	.03	.03
511–123	35.65	66.25	35.71	66.29	35.64	66.24	35.69	66.29
	.06	.05	.05	.04	.03	.03	.03	.03
511–167	36.67	67.03	36.70	67.06	36.68	67.03	36.71	67.06
	.04	.02	.04	.03	.04	.02	.04	.03
519–078	35.55	66.18	35.53	66.16	35.56	66.18	35.53	66.16
	.05	.04	.05	.04	.05	.03	.06	.05

Table 8b. Comparison of the Short- and Long-Term Infrared Repeatability for the Green Fabric Samples on the NLABS Spectro Sensor

	Short				Long			
	Moonlit		Moonless		Moonlit		Moonless	
Sample:	Ns	Ls	Ns	Ls	Ns	Ls	Ns	Ls
Greens								
600–0058	8.12	34.24	8.39	34.78	8.13	34.26	8.40	34.80
	.02	.03	.02	.03	.03	.05	.03	.05
600–057	8.39	34.79	8.68	35.35	8.40	34.80	8.68	35.37
	.02	.03	.02	.03	.02	.04	.02	.04
925–622	8.49	34.99	8.74	35.48	8.50	35.02	8.75	35.50
	.01	.01	.01	.01	.02	.03	.01	.03
925–618	8.30	34.60	8.55	35.11	8.31	34.62	8.56	35.13
	.01	.02	.01	.02	.02	.04	.02	.04
925–617	8.40	34.81	8.65	35.31	8.42	34.84	8.67	35.34
	.01	.02	.01	.02	.03	.05	.03	.05
925–614	8.70	35.41	8.96	35.90	8.71	35.42	8.97	35.92
	.01	.01	.01	.01	.02	.03	.02	.03
925–613	8.82	35.64	9.06	36.10	8.83	35.65	9.07	36.12
	.01	.01	.01	.01	.02	.03	.02	.03
925–606	8.99	35.97	9.24	36.45	9.00	35.99	9.25	36.47
	.01	.02	.01	.03	.02	.04	.02	.03
925–608	9.01	36.01	9.26	36.49	9.02	36.02	9.27	36.50
	.01	.02	.01	.02	.02	.03	.02	.03
925–601	9.06	36.11	9.31	36.58	9.06	36.11	9.31	36.57
	.02	.03	.02	.04	.02	.03	.02	.03

Table 9a. Comparison of the Short- and Long-Term Infrared Repeatability of the Tan Fabric Samples on the DPSC Spectro Sensor: Standard Deviation of Starlight Scope Values (Ns,Ls)

	Short				Long			
	Moonlit		Moonless		Moonlit		Moonless	
Sample:	Ns	Ls	Ns	Ls	Ns	Ls	Ns	Ls
Tans								
313–488	35.40	66.06	35.31	65.99	35.39	66.05	35.30	65.99
	.01	.02	.01	.02	.03	.02	.03	.02
313–332	35.60	66.21	35.56	66.19	35.61	66.22	35.58	66.20
	.03	.02	.03	.03	.03	.02	.03	.02
313–321	36.14	66.63	36.08	66.58	36.13	66.62	36.07	66.57
	.03	.02	.03	.02	.03	.04	.04	.02
313–312	35.26	65.96	35.18	65.89	35.26	65.95	35.17	65.89
	.03	.02	.03	.03	.03	.03	.03	.03
313–319	35.43	66.08	35.36	66.02	35.43	66.08	35.35	66.02
	.03	.03	.03	.02	.03	.02	.02	.03
313–640	35.64	66.24	35.61	66.22	35.64	66.24	35.60	66.22
	.03	.03	.03	.02	.04	.03	.04	.03
511–036	36.65	67.01	36.65	67.01	36.66	67.03	36.66	67.02
	.02	.02	.02	.03	.03	.03	.03	.03
511–123	35.71	66.29	35.77	66.34	35.71	66.30	35.77	66.35
	.04	.02	.04	.03	.04	.03	.04	.03
511–167	36.74	67.08	36.79	67.12	36.77	67.10	36.81	67.13
	.04	.03	.04	.03	.04	.03	.04	.03
519–078	35.65	66.25	35.63	66.24	34.67	66.27	35.65	66.25
	.04	.03	.04	.03	.04	.03	.04	.04

Table 9b. Comparison of the Short- and Long-Term Infrared Repeatability for the Green Fabric Samples on the DPSC Spectro Sensor

	Short				Long			
	Moonlit		Moonless		Moonlit		Moonless	
Sample:	Ns	Ls	Ns	Ls	Ns	Ls	Ns	Ls
Greens								
600–0058	8.19	34.37	8.45	34.91	8.19	34.38	8.46	34.92
	.01	.03	.02	.03	.01	.04	.02	.03
600–057	8.44	34.87	8.72	35.43	8.45	34.90	8.73	35.45
	.01	.03	.01	.03	.02	.04	.02	.04
925–622	8.54	35.09	8.79	35.58	8.55	35.11	8.80	35.59
	.01	.02	.01	.02	.01	.02	.01	.02
925–618	8.37	34.74	8.62	35.24	8.38	34.76	8.63	35.26
	.02	.04	.02	.04	.02	.05	.02	.05
925–617	8.47	34.94	8.72	35.44*	8.49	34.98	8.74	35.48
	.02	.04	.02	.03	.02	.04	.02	.03
925–614	8.76	35.52	9.02	36.02	8.76	35.52	9.02	36.02
	.01	.02	.01	.02	.01	.02	.01	.02
925–613	8.87	35.73	9.11	36.20	8.88	35.75	9.12	36.22
	.02	.03	.02	.03	.01	.02	.01	.03
925–606	9.05	36.08	9.30	36.55	9.06	36.09	9.31	36.57
	.01	.03	.01	.03	.01	.02	.02	.02
925–608	9.07	36.12	9.33	36.60	9.08	36.14	9.31	36.62
	.02	.03	.01	.03	.02	.03	.02	.03
925–601	9.12	36.22	9.37	36.68	9.13	36.24	9.38	36.70
	.02	.03	.02	.03	.02	.04	.02	.04

Table 10a. Comparison of Average Short-Term Values for the Two Instruments

	Average MCDM		Average ΔE*
Sample	NLABS	DPSC	
Tiles	.04± .015	.07± .020	.09± .040
Greens	.05± .014	.07± .027	.08± .028
Tans	.04± .012	.04± .007	.06± .026

Table 10b. Comparison of Average Long-Term Values for the Two Instruments

	Average MCDM		Average ΔE*
Sample	NLABS	DPSC	
Tiles	.04± .010	.09± .034	.12± .028
Greens	.06± .010	.06± .008	.10± .020
Tans	.04± .011	.04± .006	.07± .026

Table 10c. Comparison of Average Long and Short-Term Values for the NLABS Instrument

	Average MCDM		Average ΔE*
Sample	Short	Long	
Tiles	.04± .015	.04± .010	.04± .037
Greens	.05± .014	.06± .010	.05± .034
Tans	.04± .012	.04± .011	.03± .020

Table 10d. Comparison of Average Long- and Short-Term Values for the DPSC Instrument

Sample	Average MCDM		Average ΔE*
	Short	Long	
Tiles	.07± .020	.09± .034	.06± .044
Greens	.07± .027	.06± .008	.06± .041
Tans	.04± .007	.04± .006	.03± .016

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