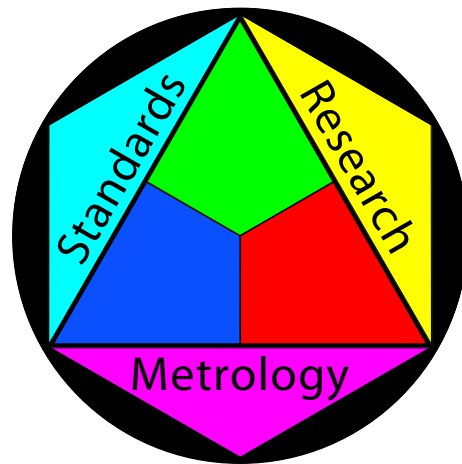


# Mt. Baker Research LLC

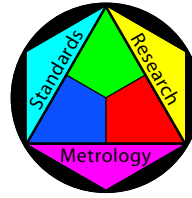


Measurement Services  
& Calibration Certificates



## Avian Technologies LLC

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Wilmington, Ohio 45177-0822  
937-655-8767 fax 937-655-8765



## Mt. Baker Research LLC

2921 Sylvan Street/P.O. Box 28370  
Bellingham, Washington 98228-0370  
360-650-0771

Customer: WS Packaging Group, Inc.

Contact: Charles Paddock Tel: 603-654-6131

P.O. No.: ATP-100907-01 Date: 10.23.07

CAL No.: MBR-071022-01

### Laboratory Conditions

Mean T:  $22.7 \pm 0.1^{\circ}\text{C}$

Humidity: 45%

Certified by: J.W. Root, Ph.D.

### Measurement Parameters

Instrument: Konica-Minolta CM-2500c NUV-VIS Spectrophotometer S/N D4001373

Geometry: (45°/0°) Bi-directional (ring illumination & vertical viewing)

Sample Port: Circular with 11 mm (illuminated) & 7 mm (viewed) diameters

Wavelength Pitch: 10 nm

Wavelength Range: 360 - 740 nm

No. Spectra per Measurement: 30

Delay between Spectra: 10 seconds

No. Averaged Measurements: 6

Traceable Reference Standard: Konica-Minolta White Reference Tile S/N 7101269

Data Media: Graph and CD Disk (certified)

Samples Measured: CERAM Cyan Tile

### Procedure

Radiance factors were measured at ambient temperature and humidity with a Konica-Minolta CM-2500c NUV-VIS spectrophotometer. This instrument operates in the (45°/0°) bi-directional geometry, and outputs radiance factors from 360 - 740 nm in 10 nm intervals. (Radiance factors measured in the (0°/45°) and (45°/0°) geometries are identical.) CyberChrome OnColor QC Premium® software was used to operate the spectrophotometer, average the replicate spectra obtained during each measurement series, and perform colorimetric analysis. Radiance factors were measured relative to the calibrated (traceable) Konica-Minolta white reference tile supplied with this instrument.

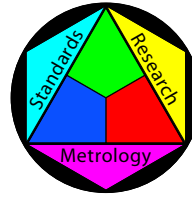
The calibrations optimized the statistical quality of the radiance factors by averaging over 30 replicate measurements for each sample followed by 30 measurements of the white reference tile (accurately calibrated in the (0°/45°) geometry). This sequence was repeated 3 times with sample replacement and re-calibration of the instrument between each measurement series.

Repeatability and accuracy measurements were based on repeated measurements of the Konica-Minolta White reference tile and 2 ceramic transfer standards (Avian Technologies #B-5 White and #P-6 Light Green), which were calibrated recently at the National Research Council of Canada. Colorimetry: Based on 23 independent measurements of the Konica-Minolta White tile with replacement and re-calibration between measurements, the typical repeatability of the spectrophotometer was  $\Delta E^*_{ab} = 0.028 \pm 0.016$ . (The measurement uncertainties listed here are standard deviations.) For this instrument Konica-Minolta specifies a repeatability within  $\Delta E^*_{ab} = 0.05$  (white reference tile measured 30 times without replacement or re-calibration between measurements), and an inter-instrument agreement within  $\Delta E^*_{ab} = 0.25$  (average for 12 CERAM BCRA Series II tiles). Radiance Factors: For the calibrated #B-5 White tile, the average  $2\sigma$  standard error (95% confidence level) was  $0.44 \pm 0.17$ . Based on the NRC data for this tile, the corresponding average absolute error was  $0.38 \pm 0.16$ . For the calibrated #P-6 Light Green tile the average  $2\sigma$  standard error was  $0.28 \pm 0.07$ , and the average absolute error was  $0.32 \pm 0.12$ . These results show that our  $2\sigma$  standard errors provide a valid estimate of accuracy.



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### Notes – Certified Data

1. Graphs and CIELAB data are provided for informational purposes only. The accompanying CD-R disk contains the certified reflectance data for this set of tiles. The CIELAB parameters included on the disk are not certified.

### Notes – Basis for Traceability

1. NRC Calibration Report No. PAR-2007-2528, 2007, "0°:45° Radiance Factors of Two Ceramic Tiles, S/N: P-6-Light-Green, B-5-White," National Research Council Canada, Institute for National Measurement Standards, Ottawa, Canada, [www.nrc-cnrc.gc.ca](http://www.nrc-cnrc.gc.ca).
2. ASTM E1349-06, 2006, "Standard Test Method for Reflectance Factor and Color by Spectrophotometry Using Bidirectional (45:0 or 0:45) Geometry," ASTM International, West Conshohocken, PA, [www.astm.org](http://www.astm.org).
3. ASTM E1345-98, 1998 (2003), "Standard Practice for Reducing the Effect of Variability of Color Measurement by Use of Multiple Measurements," ASTM International, West Conshohocken, PA, [www.astm.org](http://www.astm.org).

### Technical References

1. ASTM E275-01, 2001, "Standard Practice for Describing and Measuring Performance of Ultraviolet, Visible, and Near-Infrared Spectrophotometers," ASTM International, West Conshohocken, PA, [www.astm.org](http://www.astm.org).
2. ASTM E2214-02, 2002, "Standard Practice for Specifying and Verifying the Performance of Color-Measuring Instruments," ASTM International, West Conshohocken, PA, [www.astm.org](http://www.astm.org).
3. ASTM E1164-07, 2007, "Standard Practice for Obtaining Spectrometric Data for Object-Color Evaluation," ASTM International, West Conshohocken, PA, [www.astm.org](http://www.astm.org).
4. ASTM E308-06, 2006, "Standard Practice for Computing the Colors of Objects by Using the CIE System," ASTM International, West Conshohocken, PA, [www.astm.org](http://www.astm.org).
5. CIE 15:2004, "CIE Technical Report: Colorimetry," 3rd edition, International Commission on Illumination (Commission Internationale de l'Eclairage), Vienna, Austria, ISBN: 3-901-906-33-9, [www.cie-usnc.org](http://www.cie-usnc.org).
6. D.R. Wyble, D.C. Rich, "Evaluation of Methods for Verifying the Performance of Color-Measuring Instruments. Part I: Repeatability," *Color Research and Application*, 32(3), 166(10), 2007.
7. D.R. Wyble, D.C. Rich, "Evaluation of Methods for Verifying the Performance of Color-Measuring Instruments. Part II: Inter-Instrument Reproducibility," *Color Research and Application*, 32(3), 176(19), 2007.

### General References

1. ISCC Technical Report 2003-1, 2003, J. Ladson, A.W. Springsteen, J. Sefl, H.S. Fairman, M.H. Brill, and J. Zwinkels, "Guide to Material Standards and Their Use in Color Measurement," Inter-Society Color Council, Reston, VA, [www.iscc.org](http://www.iscc.org).
2. R.S. Berns, "Billmeyer and Saltzman's Principles of Color Technology," 3rd edition, John Wiley & Sons, Inc., New York, 2000, ISBN: 978-0-471-19459-0, [www.wiley.com](http://www.wiley.com).
3. M.D. Fairchild, "Color Appearance Models," 2nd edition, John Wiley & Sons, Ltd., Chichester, England, 2005, ISBN: 0-470-01216-1, [www.wiley.com](http://www.wiley.com).
4. "Spectrophotometer CM-2500c Instruction Manual," Konica-Minolta Sensing Americas, Inc., Ramsey, NJ, [www.se.konicaminolta](http://www.se.konicaminolta).

(45/0) Radiance Factors for CERAM Cyan Tile

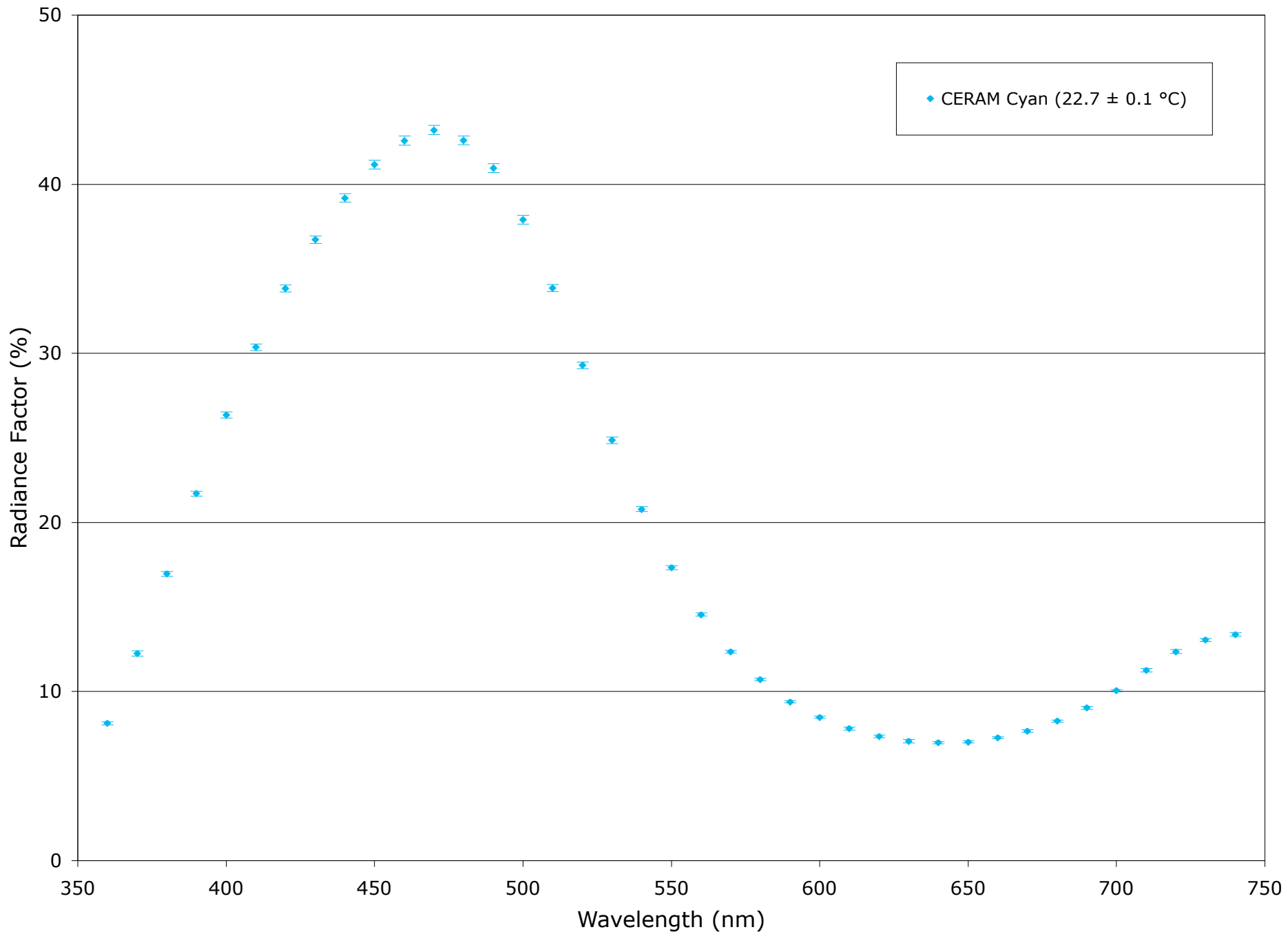


Table 1. Averaged Radiance Factor Values

Wavelength (nm)	Radiance Factor (%)	Standard Error (%)
360	8.12	0.09
370	12.25	0.15
380	16.97	0.14
390	21.71	0.15
400	26.35	0.18
410	30.36	0.20
420	33.83	0.21
430	36.73	0.22
440	39.18	0.25
450	41.15	0.26
460	42.57	0.27
470	43.21	0.28
480	42.60	0.26
490	40.95	0.25

Table 1. Averaged Radiance Factor Values Continued

Wavelength (nm)	Radiance Factor (%)	Standard Error (%)
500	37.90	0.26
510	33.86	0.22
520	29.29	0.19
530	24.86	0.18
540	20.79	0.14
550	17.33	0.12
560	14.56	0.10
570	12.36	0.08
580	10.71	0.07
590	9.39	0.07
600	8.48	0.07
610	7.81	0.10
620	7.35	0.08
630	7.07	0.10

Table 1. Averaged Radiance Factor Values Continued

Wavelength (nm)	Radiance Factor (%)	Standard Error (%)
640	6.98	0.06
650	7.02	0.06
660	7.27	0.06
670	7.65	0.08
680	8.26	0.06
690	9.04	0.09
700	10.05	0.07
710	11.26	0.10
720	12.37	0.11
730	13.06	0.09
740	13.36	0.10

Table 2. Averaged CIELAB Values with Standard Deviations

Standard Illuminant	Standard Observer	X	Y	Z	L*	a*	b*
D65	2°	15.455	18.741	43.458	50.383	-13.225	-32.801
		±0.005	±0.007	±0.019	±0.008	±0.007	±0.011
A	2°	12.365	15.311	14.188	46.057	-26.069	-40.208
		±0.004	±0.005	±0.006	±0.007	±0.011	±0.013
C	2°	16.229	18.599	47.205	50.215	-10.903	-33.106
		±0.006	±0.007	±0.021	±0.008	±0.006	±0.011