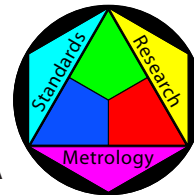


# Spectral Reflectance Factors for New Ceramic Transfer Standards

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# Contents of Catalog

SUMMARY: This catalog describes the Transfer Standards project and presents 10 charts containing reflectance factor data for the new glossy collection. A Contents page, which lists the individual charts, precedes each series.

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## Viewing the Catalog

Dr. Root created these charts with Microsoft Excel 2004 (Mac v. 11.3.3), Word 2004 (v. 11.3), Adobe InDesign (v. 4.0.5), Illustrator (v. 11.0.0), and Acrobat Professional (v. 8.0.0). The charts are formatted for viewing with Adobe Acrobat Reader (v. 7.0.9 or newer). Do not attempt to view the Catalog with other viewers, including Apple Preview.

Although the charts may be viewed using any screen resolution, the detail is improved for XGA (1,024 x 768) or better. If possible, use a resolution of 1,600 x 1,000, 1,280 x 960, or higher. Additional detail may be achieved with the aid of the Zoom tool in Acrobat Reader. From the keyboard execute command-+ (Mac) to zoom in, command-- to zoom out, or command-0 to restore normal size. Depending on the magnification level, you may notice occasional problems with line positioning and line weights. These artifacts result from the less-than-perfect conversion of Excel charts to the .pdf format.

In Acrobat Reader access individual drawings for viewing or printing using the Contents pages and the Bookmarks tool. In the hierarchical bookmarks menu, the charts in each series are nested below the introductory Contents page.

Use the Full Screen presentation tool in Acrobat Reader to view the entire catalog. Open the Catalog in Acrobat Reader and execute Full Screen View from the Window sub-menu, or command-L (Mac) from the keyboard. With this viewing method use the left and right mouse buttons to step through the charts in forward or reverse sequence. The arrow keys, the Home and End keys, and the zoom tool are active as well. Execute a second command-L to exit Full Screen View.

## Project History

Early in 2006 Mt. Baker Research began developing new transfer standards produced from commercial monochromatic ceramic tiles. We evaluated the tiles distributed in North America by more than 20 international manufacturers and acquired several hundred samples. After selecting the best varieties, we purchased the 8,000 tiles that make up our present production inventory.

Dr. Art Springsteen (Avian Technologies L.L.C.) supported the project by measuring reflectance factors for more than 100 glossy tiles (see below). Dr. Jack Root performed the background research, analyzed and documented the reflectance factor data, and developed the procedures used to manufacture the standards. At present he oversees production, which is carried out at Mt. Baker Research L.L.C.

The color standards described here are available for distribution now, but this remains a work in progress. We have commissioned several experts to evaluate the standards. During 2007 we will refine the collection and develop other sets. We are actively developing small mosaics, or arrays, of tiles for use in the calibration of hand-held instruments with small spot size. In addition to the sets we offer individual tiles in standard sizes and custom sizes to fit particular applications, such as online or scanning instruments. Our spectral palette includes several hundred colors. All of these tiles are available on a custom basis.

During the coming year we plan to measure thermochromism on key glossy tiles, calculate nominal CIELAB color coordinates, and publish spectral data for all of our available tiles.

## Overview of Sets

The new expanded ceramic tile color standard sets described in this catalog are used for instrument profiling and offer the widest color gamut of any collection of standards on the market. They are being offered as three sets of sixteen 2" square tiles. The Basic Colors Set is based on the CERAM Series II tiles, with the addition of 4 new tiles — black, white, difference yellow, and difference blue. The Grey and Pastel Colors Set offers a wider range of grey scale along with a broad palette of pastels related to the primary color set. The Special Colors Set expands the color gamut with the addition of 16 additional dark and saturated colors not offered in the CERAM sets.

Each tile is mounted in a Delrin holder and identified with a label placed inside the positioning device on the back of the holder. Each mounted standard is enclosed in a non-contaminating, non-woven optical component envelope. Each set is supplied in a hermetically sealed box, keeping the tiles protected and allowing for easy transport or storage.

All sets include a booklet with 'typical' ( $8^\circ$ /hemispherical) reflectance factor data. Calibration is available, traceable to NRC/NIST at ( $8^\circ$ /hemispherical) geometry. We expect to be able to offer traceable calibrations for ( $0^\circ/45^\circ$ ) radiance factor by September of 2007. For additional information consult the Web site for Avian Technologies L.L.C. at <http://www.avianttechnologies.com/>.

Please contact Art Springsteen or Jack Root for pricing and technical information, and let us know how to best meet your needs.

## Measurements at Avian Technologies L.L.C.

Dr. Art Springsteen measured reflectance factors using a Perkin-Elmer Lambda 9/19 UV-VIS-NIR spectrophotometer equipped with a Labsphere 150 mm integrating sphere accessory. The instrument was configured for the specular included ( $8^\circ/t$ ), or total hemispherical, geometry.

Dr. Springsteen performed all measurements using a 2 nm bandpass at 1 nm intervals from 360 – 830 nm at ambient temperature ( $20^\circ \pm 1^\circ\text{C}$ ) and humidity ( $39\% \pm 5\%$ ). He measured the reflectance factors relative to freshly packed Teflon (Dupont 7A) powder in accord with ASTM Practice E259-98 and CIE Technical Report 15.2.

## Reference Data for Ceram Standards

In addition to the new standards described in this catalog, Mt. Baker Research L.L.C. maintains the following collection of calibrated transfer standards: 27 Ceram tiles (Ceram Research Ltd.), 13 ceramic tiles distributed by GretagMacbeth AG, black and white glass reflectance standards, Fluorilon, and 14 plastic standards produced by Color Control Systems and distributed by Avian Technologies L.L.C.

Early in 2005, we purchased the following calibrated standards from Avian Technologies L.L.C.: 12 Ceram BCRA Series II ceramic standards, 6 extra achromatic standards, and 4 extra chromatic standards. Dr. Arthur W. Springsteen calibrated each standard in the ( $8^\circ/d$ ) specular excluded, or diffuse only, geometry and the ( $8^\circ/t$ ) specular included, or total hemispherical, geometry.

A master catalog of spectral reflectance factor and radiance factor data for our Ceram standards is available from Dr. Root. The data are graphed using a wavelength interval of 5 or 10 nm and accompanied by single-sigma standard errors of estimate.

## Capsule Biographies & Resources

Dr. John W. Root is the president and CTO at Mt. Baker Research L.L.C. He is a retired professor of chemistry from the University of California, Davis, and computer scientist from the Los Alamos National Laboratory, New Mexico. A former Guggenheim Fellow and experienced researcher, he has held memberships in numerous professional societies and authored more than 200 technical publications, reports, and presentations. Presently he is a member of the Inter Society Color Council. He holds a Ph.D. in physical chemistry from the University of Kansas and a Postdoctoral Certificate in radiochemistry from UCLA.

Since 1999 Dr. Root has pursued full-time research and development in digital imaging, color management, and color science. Late in 2004 he focused on the use of ceramic transfer standards for calibrating and profiling instruments used for measuring color. He purchased Ceram standards and used them to benchmark the GretagMacbeth EyeOne Pro spectrophotometer. After deciding to develop new standards, he evaluated numerous commercial ceramic tiles, analyzed and documented the reflectance factor data generated for them, evaluated and tested methods for machining ceramics and for producing the new standards, and developed procedures for assembly and quality control. At present he oversees production of the standards, which is carried out at Mt. Baker Research L.L.C.

Dr. Root's laboratory includes networked state-of-the-art computers and equipment for the measurement, analysis, and reproduction of color in a color-managed environment. During 2006 we purchased the equipment and materials needed to manufacture and test the new ceramic standards. In addition, we acquired GretagMacbeth ColorEye 2145 and 7000A spectrophotometers supported by Color iQC software.



Dr. Arthur W. Springsteen is the president and CTO at Avian Technologies L.L.C. Avian Technologies specializes in the design and manufacture of instruments and standards for optical spectrometry and other optical radiation measurements. Prior to starting Avian Technologies in 1999, Dr. Springsteen was Principal Scientist and Director for Advanced Development at Labsphere Inc. for 13 years. During his tenure at Labsphere, he developed over 30 commercial products, including the Spectralon® diffuse reflectance material product line, numerous optical coatings, fluorescent materials and accessories for measurement of reflectance, diffuse transmittance and fluorescence. He holds five U.S. patents (and has three pending) on materials and instrument design, won a 1990 Photonics Spectra New Product of the Year award (Optical Grade Spectralon®), and shared another in 1997 for the development of the Labsphere bispectral fluorescence colorimeter. He has published over thirty scientific papers and may often be seen in the pages of Spectroscopy Magazine's "Spectroscopy Workbench" section. He is also co-author/editor (with Jerry Workman) of the Academic Press book "Applied Spectroscopy, A Complete Guide for Practitioners," and edited the Proceedings of the Third and Fourth Oxford Conferences on Spectrometry. He is a member and former Secretary for the Council for Optical Radiation Measurement, a member of the Board of Directors of the Inter Society Color Council, and a former member of the National Research Council of the U.S. He is also an active member of ASTM Committees E-12 (Color and Appearance) and E-13 (Molecular Spectroscopy), the Society for Applied Spectroscopy, and Council for Near-Infrared Spectroscopy. He holds a Ph.D. from West Virginia University in Organic Chemistry.

## Contents—Basic Colors Charts

SUMMARY: The Basic Colors Set parallels the CERAM Series II tiles set with a few changes. Both a white and a black tile are included, as well as difference blue and difference yellow pairs in place of the CERAM difference green and difference grey pairs. The set contains 5 achromatic tiles and 11 chromatic tiles. Typical ( $8^\circ$ /hemispherical) reflectance factor data are presented here on 4 charts. The individual tiles are listed below in the same sequence in which they appear on these charts.

Chart A: Achromatic Standards (#B-5 White, #B-1 Light Grey, #B-6 Mid-Grey, #B-7 Deep Grey, & #B-8 Black)

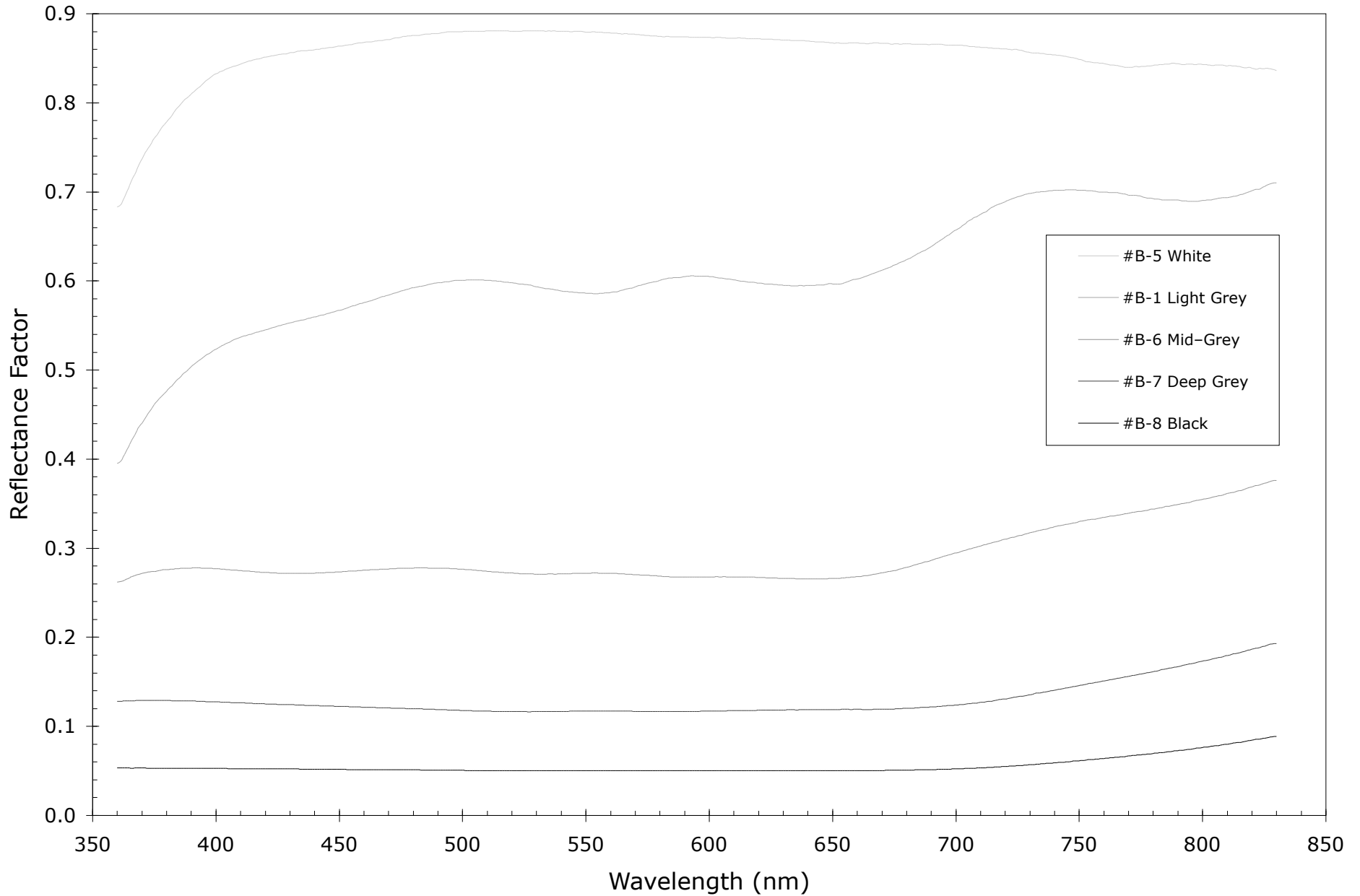
Chart B: Achromatic Standards (#B-5 White, #B-5A White Alternate, #B-1 Light Grey, #B-6 Mid-Grey, #B-7 Deep Grey, & #B-8 Black)

Chart C: Chromatic Standards—Blues & Green (#B-14 Deep Blue, #B-11 Mid-Blue, #B-4 Difference Mid-Blue, #B-13 Cyan, & #B-10 Deep Green)

Chart D: Chromatic Standards—Yellows, Oranges, & Reds (#B-9 Yellow, #B-3 Difference Yellow, #B-15 Mid-Orange, #B-12 Deep Red-Orange, #B-2 Red, & #B-16 Deep Rose-Pink)

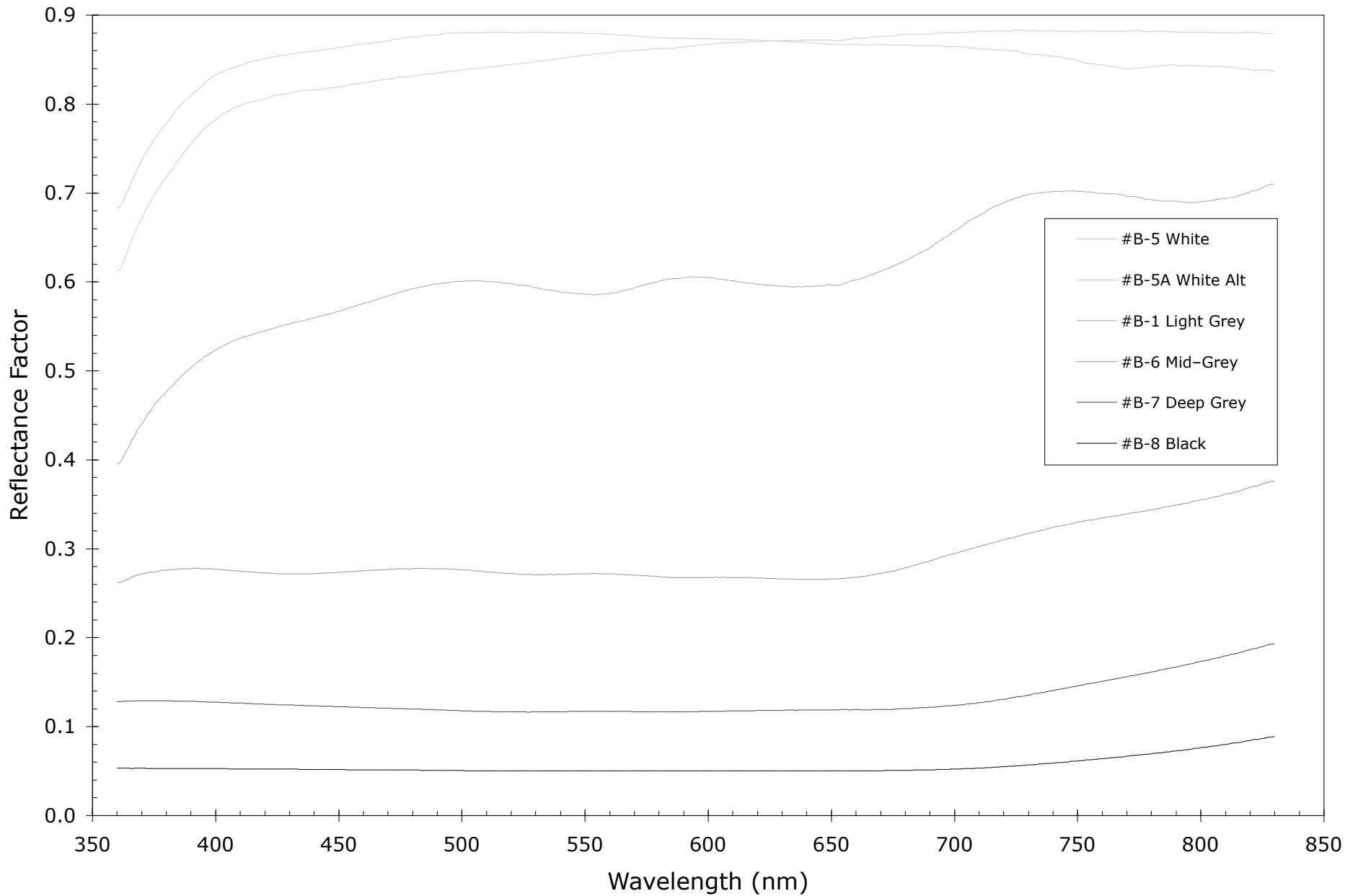
# Avian Technologies Basic Colors Tile Set

Average Results for (8°/t) Geometry & 2 nm Bandpass



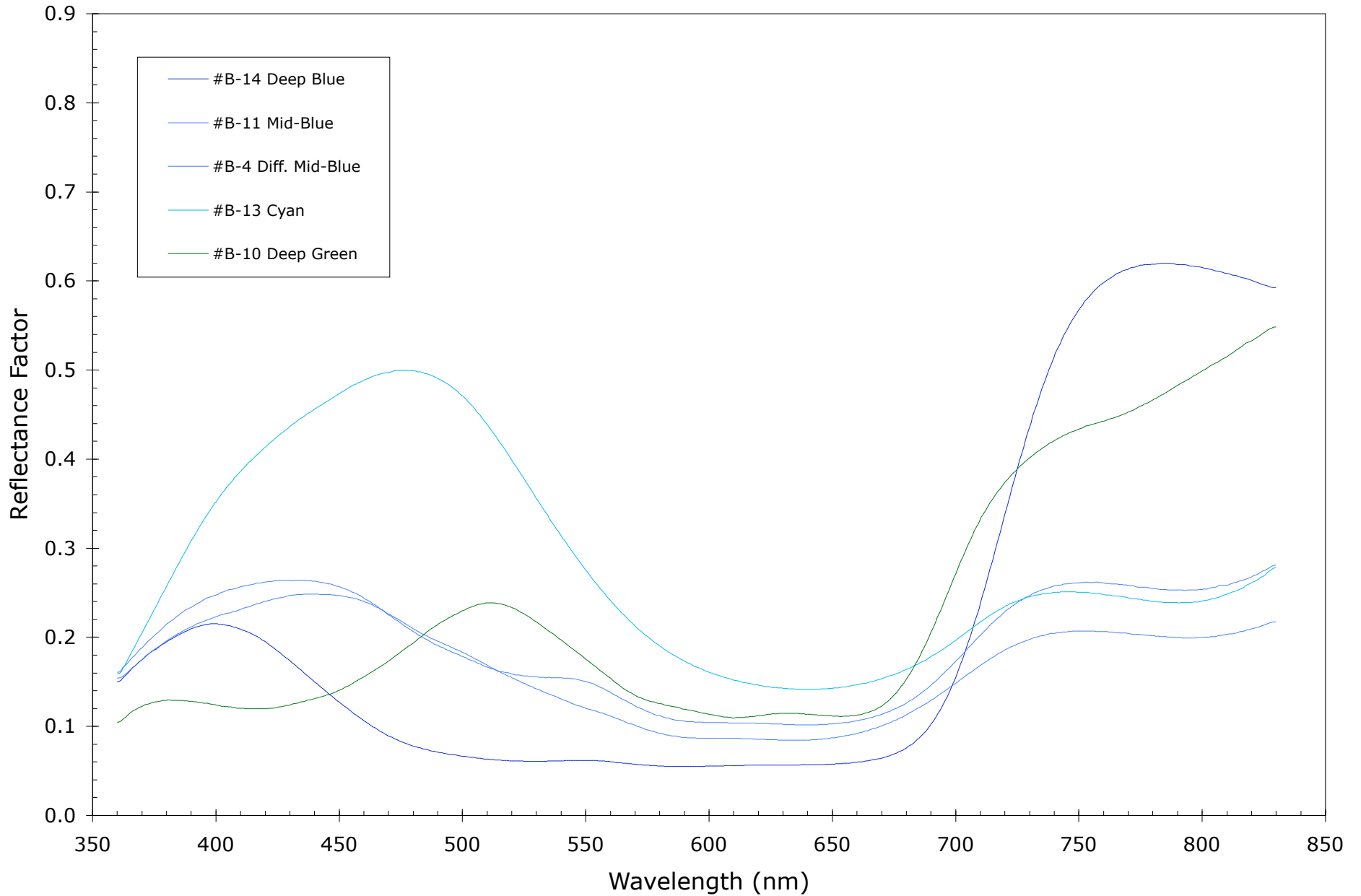
# Avian Technologies Basic Colors Tile Set

Average Results for (8°/t) Geometry & 2 nm Bandpass



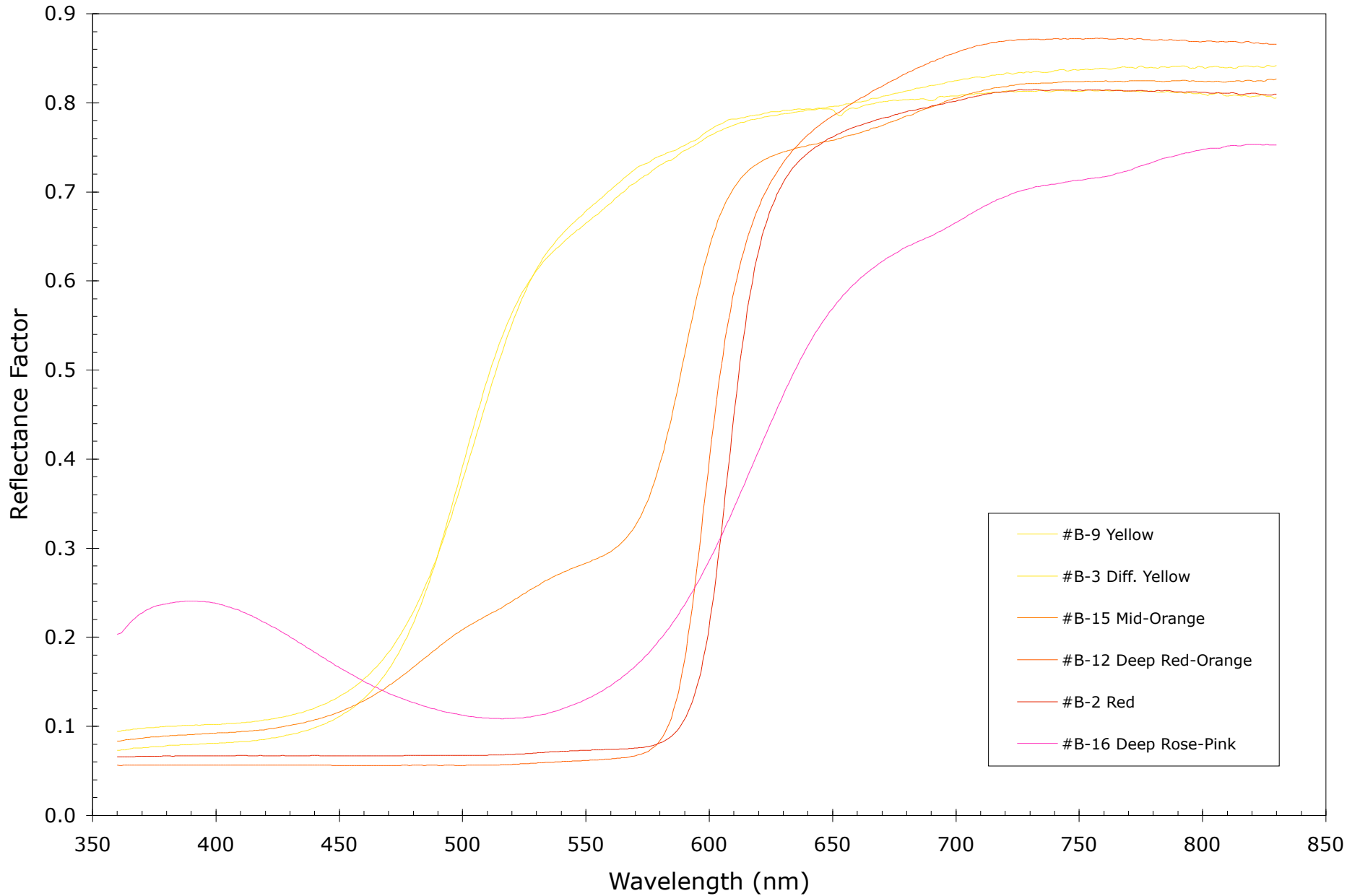
# Avian Technologies Basic Colors Tile Set

Average Results for (8°/t) Geometry & 2 nm Bandpass



# Avian Technologies Basic Colors Tile Set

Average Results for (8°/t) Geometry & 2 nm Bandpass



## Contents—Special Colors Charts

SUMMARY: The Special Colors Set offers a wider gamut of saturated colors to enhance the Basic Colors Set. The 16 tiles offer colors that are not normally found in color tile sets, including a deep violet difference pair and a deep brown. This set is especially strong in the purple to violet range. It aims to extend the gamut of the CERAM Series II set. Typical (8°/hemispherical) reflectance factor data are presented here on 3 charts. The individual tiles are listed below in the same sequence in which they appear on these charts.

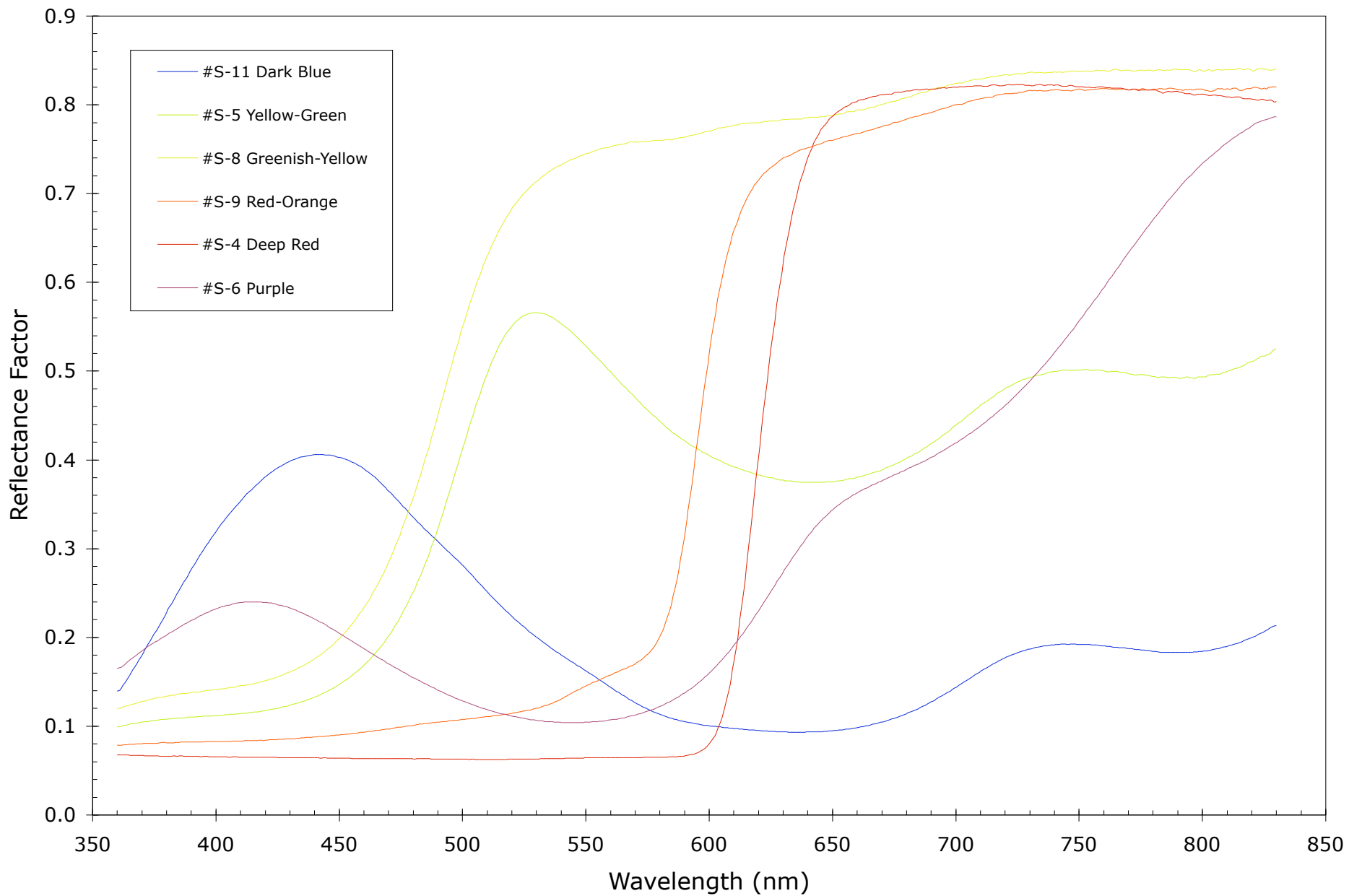
Chart A: Chromatic Standards (#S-11 Dark Blue, #S-5 Yellow-Green, #S-8 Greenish-Yellow, #S-9 Red-Orange, #S-4 Deep Red, & #S-6 Purple)

Chart B: Chromatic Standards (#S-10 Greenish-Blue, #S-13 Mid-Green, #S-7 Yellow-Orange, #S-2 Deep Violet, & #S-3 Difference Deep Violet)

Chart C: Chromatic Standards (#S-1 Dark Blue-Violet, #S-12 Mid-Brown, #S-14 Dark Green, #S-15 Dark Purple, & #S-16 Dark Brown)

# Avian Technologies Special Colors Tile Set

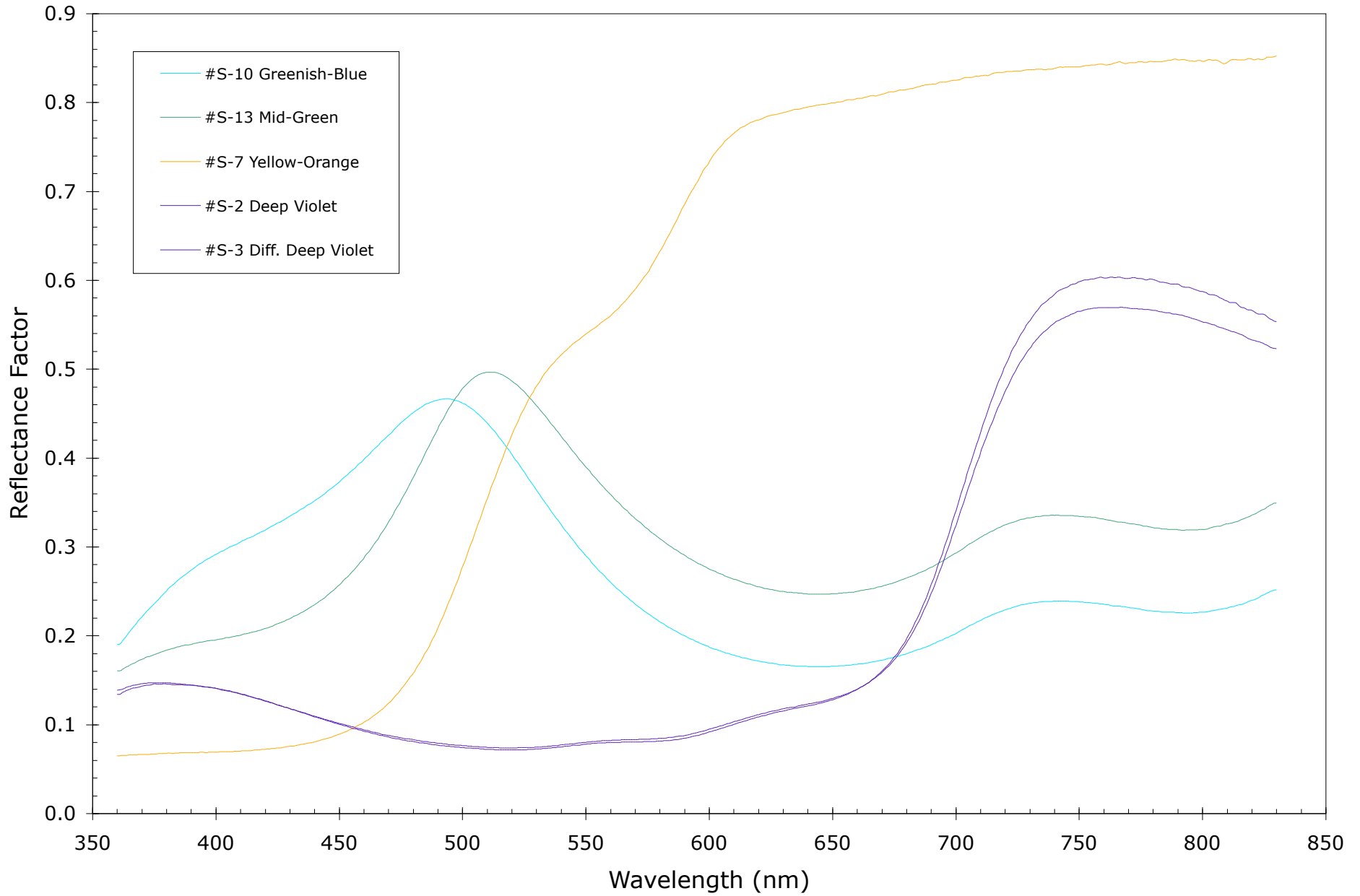
Average Results for (8°/t) Geometry & 2 nm Bandpass





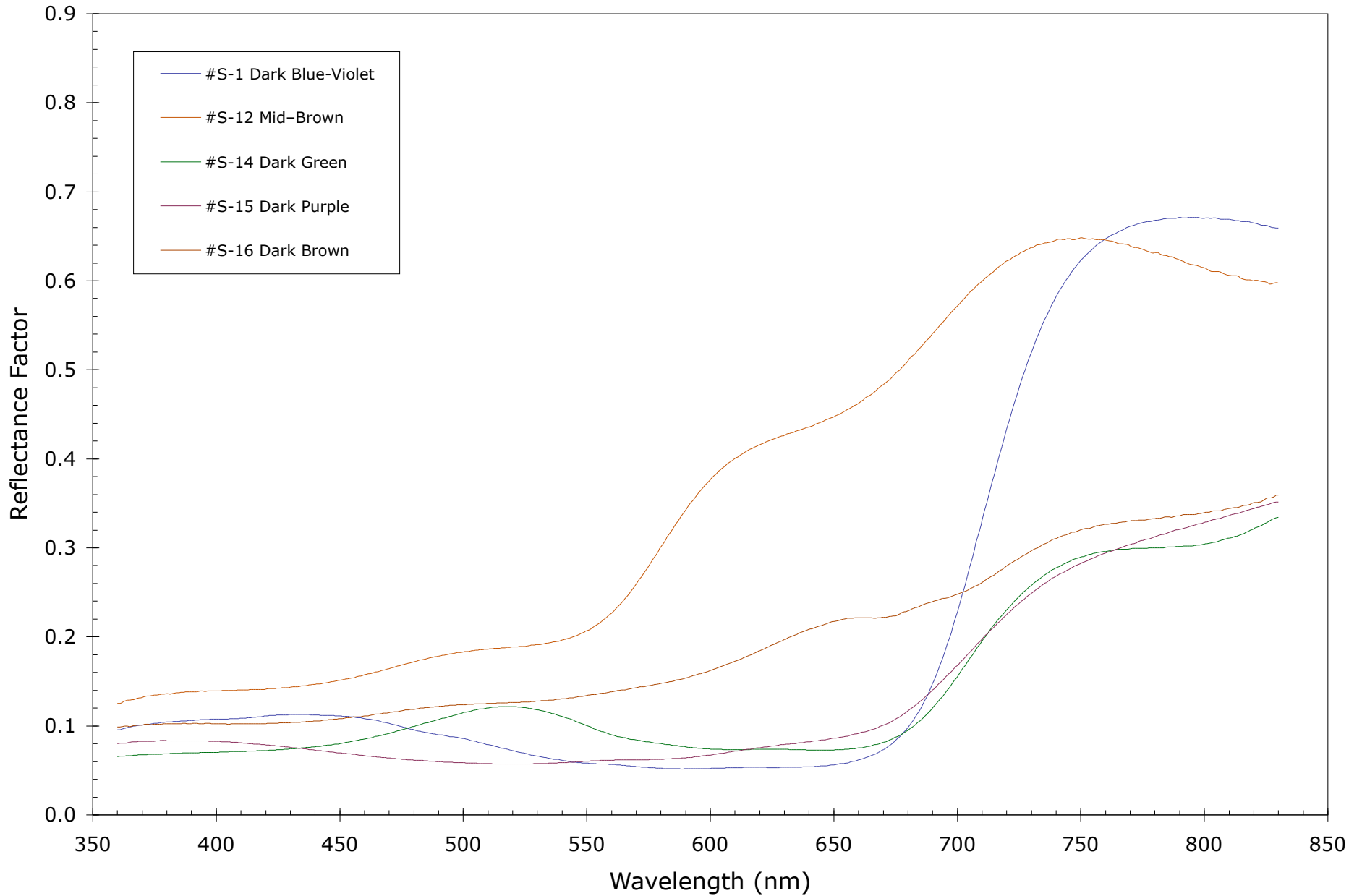
# Avian Technologies Special Colors Tile Set

Average Results for (8°/t) Geometry & 2 nm Bandpass



# Avian Technologies Special Colors Tile Set

Average Results for (8°/t) Geometry & 2 nm Bandpass



## Contents—Grey & Pastel Colors Charts

SUMMARY: The Grey and Pastel Colors Set extends the range of the Basic Color Set by adding a wide range of grey scale, including a difference 50% grey pair. In addition, the set includes a wide range of pastel tiles, which are based on the more saturated colors in the Basic Colors Set. This set contains 7 achromatic tiles and 9 chromatic tiles. Typical (8°/hemispherical) reflectance factor data are presented here on 3 charts. The individual tiles are listed below in the same sequence in which they appear on these charts.

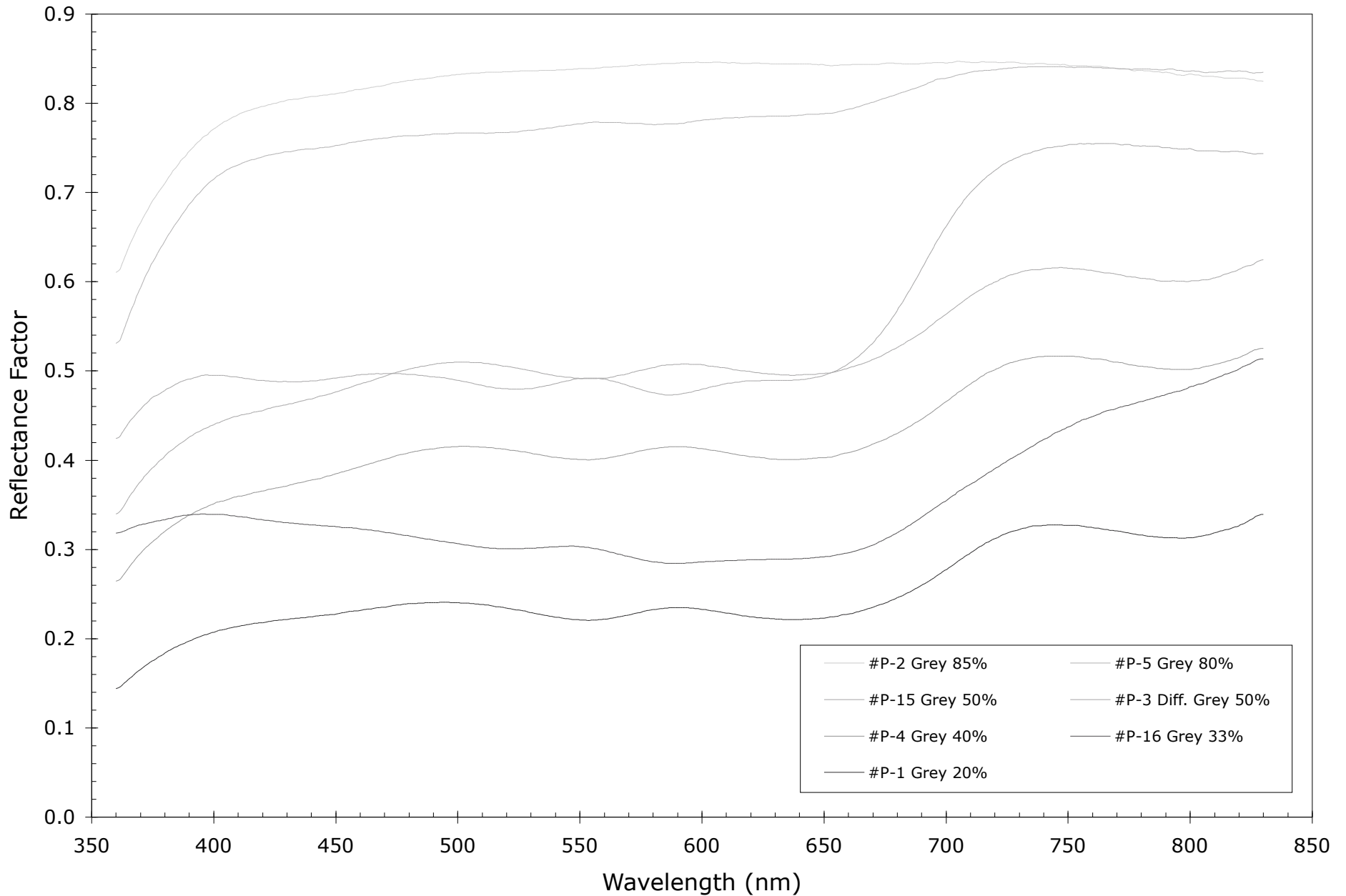
Chart A: Achromatic Standards (#P-2 Grey 85%, #P-5 Grey 80%, #P-15 Grey 50%, #P-3 Difference Grey 50%, #P-4 Grey 40%, #P-16 Grey 33%, & #P-1 Grey 20%)

Chart B: Chromatic Standards (#P-13 Light Blue, #P-12 Light Cyan, #P-10 Light Blue-Green, & #P-6 Light Green)

Chart C: Chromatic Standards (#P-11 Light Yellow-Green, #P-8 Light Yellow, #P-7 Light Orange, #P-9 Light Pink, & #P-14 Rose-Pink)

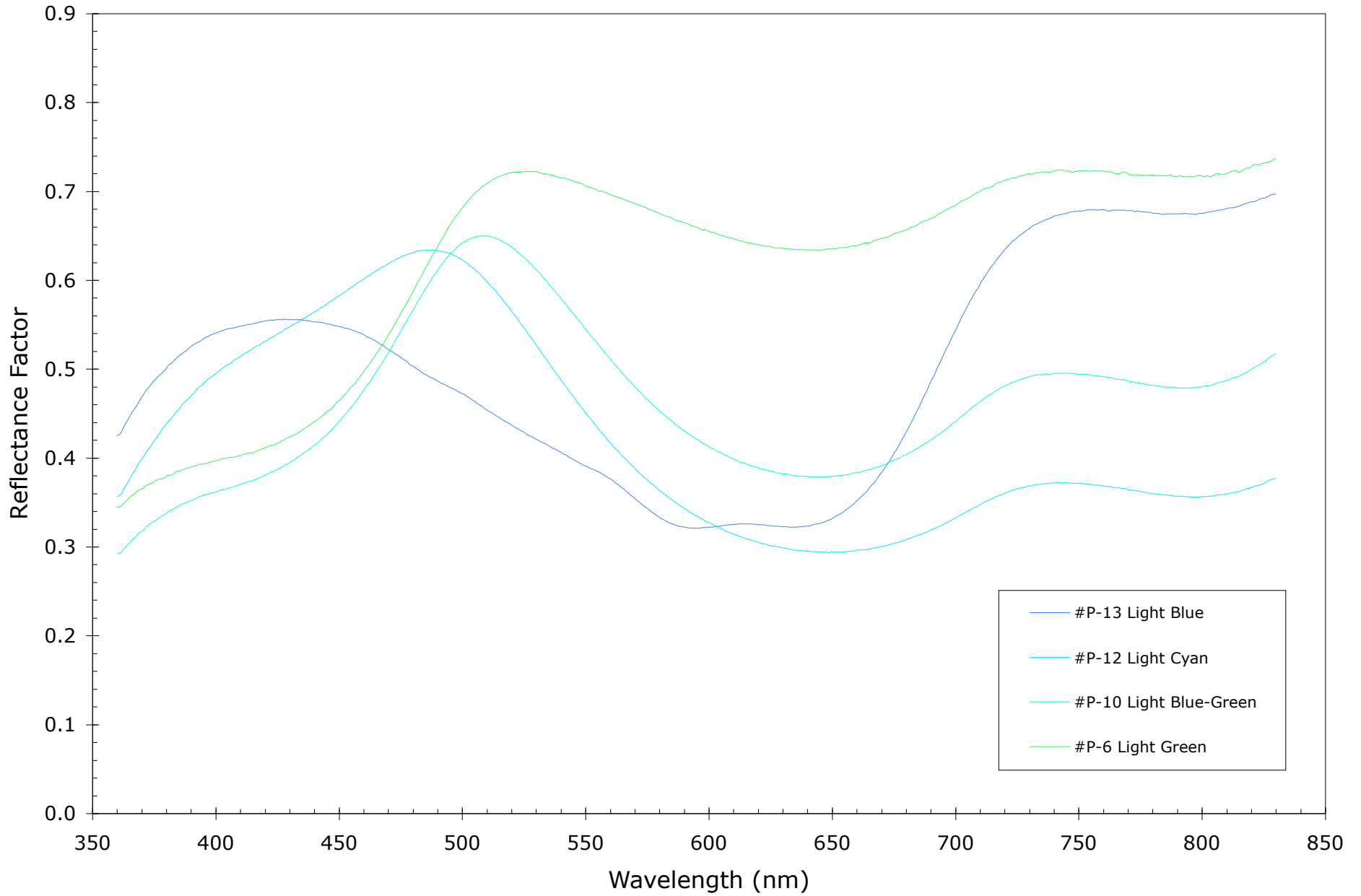
# Avian Technologies Grey & Pastel Colors Tile Set

Average Results for (8°/t) Geometry & 2 nm Bandpass



# Avian Technologies Grey & Pastel Colors Tile Set

Average Results for (8°/t) Geometry & 2 nm Bandpass



# Avian Technologies Grey & Pastel Colors Tile Set

Average Results for (8°/t) Geometry & 2 nm Bandpass

