UV Calibration and Whiteness FAQs

Whiteness indices, computed by such software as Datacolor TOOLS, are used in association with UV-enhanced spectrophotometers such as the Datacolor 600, 650, Elrepho, and Check PRO. Such indices are used mainly by the textile and paper industries where whiteness is important, particularly when optical brighteners are included in the product. An optical brightener enhances the whiteness of paper or textiles by absorbing the ultraviolet (UV) part of the daylight spectrum and re-emitting the energy as visible light. This phenomenon is known as fluorescence. Because whiteness depends on the UV content of the incident light, whiteness indices rely on careful control of the UV content of the spectrophotometer's light source. Two commonly used whiteness indices are the Ganz-Griesser whiteness and the CIE Whiteness Index. Material standards used to calibrate whiteness via these indices include Hohenstein, AATCC, Paprican, and STFI. This FAQ should lead a user through more details about the terminology, determination, and limitations of such whiteness indices and material standards.

1. **What are optical brighteners?** Optical Brightening Agents (OBA's), also referred to as Fluorescent Whitening Agents (FWA's), are chemicals containing molecules that fluoresce. When they are applied to white materials they give the material the appearance of being "whiter than white."

2. **What is fluorescence?** Natural daylight is not limited to the wavelengths of the visible spectrum (400 – 700nm). It includes radiation from the entire electromagnetic spectrum including the UV. When radiation of the right wavelength strikes a fluorescent molecule, it excites the molecule and is absorbed by it. As the molecule returns to its previous state, it emits the absorbed energy as visible light, rather than heat. In the case of OBA's, UV energy is absorbed by the molecule and re-emitted in the blue region of the visible spectrum, around 450 nm.

   For white materials, an increase in the energy reflected in the blue region results in the white appearing 'bluer'. A 'bluer' white is perceived as 'cleaner', but a white material that has aged or become dirty appears to be yellow and is less acceptable to the eye. As a result, OBA's are commonly added to white fabrics and other white materials to make them appear 'bluer' or 'cleaner'.

3. **What is a UV-enhanced spectrophotometer?** Because the amount of OBA fluorescence is directly related to the amount of energy absorbed by the fluorescent molecule, a UV-enhanced spectrophotometer (generally one based on an integrating sphere) must have a light source that emits the right amount of ultra-violet light---typical of normal daylight, which standards bodies have agreed to be CIE Illuminant D65. The light sources in such spectrophotometers (such as pulsed-xenon light sources) start out by containing proportionally more UV energy than D65. A variable-position UV cutoff filter is then used to control the UV so as to simulate D65. The filter is placed in front of the beam before it enters the sphere.

4. **How often must I readjust the UV filter in my whiteness-measuring spectro-photometer?** As an integrating-sphere spectrophotometer ages, the barium-sulfate coating in the sphere increasingly absorbs the ultraviolet light emitted from the source. Also, the UV light emitted from the light source changes with time. To compensate, you must adjust the filter to control the UV power in the source. Adjusting the UV filter involves a "UV calibration" procedure that is separate from the daily calibration routine. Once the UV filter is adjusted, it does not have to be re-adjusted to measure non-

fluorescent samples. However, to measure whiteness, you must recalibrate the UV-filter setting regularly---we recommend weekly.

5. **How is the UV-filter setting calibrated at the factory?** As a rule, Datacolor no longer calibrates the UV-filter setting at the factory, but offers a new optional factory calibration service on new instruments for customer-specified whiteness standards. Datacolor does test every instrument's UV capabilities and performance, so your new instrument is guaranteed to be able to calibrate to any of the standards mentioned below. It is important for the customer to decide which of the following UV calibration methods are best suited for their applications: Ganz-Griesser whiteness using Hohenstein textile reference specimens, the CIE Whiteness Index using AATCC textile reference specimens, the CIE Whiteness Index using appropriate paper reference specimens (Paprican, STFI, or other), and ISO Brightness using the above-noted paper reference specimens. (See FAQ 12.)
6. **What is the purpose of the fluorescent tile?** The fluorescent tile is intended as a transfer (or working) standard to allow the user to update the calibration after first calibrating with the appropriate primary-reference specimens. The tile is useful because it is less fragile than the primary reference specimens, so its measurements can be trusted for a much longer time. To use the tile, measure its whiteness values immediately after the primary-reference calibration using the filter settings and instrument values determined from that calibration. From these measurements, you can assign up to four different whiteness values to a fluorescent tile. The values are the following: (a) The Ganz-Griesser whiteness measured at the Ganz-Griesser filter setting (the associated instrument parameter values being automatically inherited from the Hohenstein calibration); (b) the D65/10^{o} CIE Whiteness Index measured at the paper-standard (e.g., Paprican) filter setting; (c) the reference ISO Brightness at the setting for which C/2^{o} CIE Whiteness Index is measured; and (d) a legacy D65/10^{o} CIE Whiteness Index measured at the Ganz-Griesser filter setting. [Before 2004, only the Ganz-Griesser procedure was used to perform UV calibration, and that accounts for the legacy value for CIE Whiteness. Some textile customers may still need this setting.]

   The schedule of filter-setting calibration should be integrated with a longer schedule for replacing your primary standards such as Hohenstein, Paprican, STFI, or AATCC. Generally such replacement should be done annually, although in some cases a 3-month replacement cycle is recommended.

   Below is a common practice for UV calibration that incorporates both the primary (absolute whiteness) standard and the transfer (working) standard:

   1. Set the measurement conditions of the instrument system as found in the primary-standard documentation.
   2. Perform the usual Black and White Calibration.
   3. Calibrate the instrument for UV using the primary standard.
   4. (UV) Characterize the UV working standard (fluorescent tile).
   5. Enter the obtained Whiteness value in the software as the UV standard target (IST) value.
   6. Until the next Absolute UV Calibration, weekly calibrate the instrument for UV using the UV working standard.

7. **For Ganz-Griesser calibration, how should I later use the values I first measured with the fluorescent tile?** The values you will use comprise option (a) of FAQ 5. In the "UV Calibration Setup" menu of Datacolor TOOLS, select "UV D65/10 (Ganz Griesser)." Type the Ganz-Griesser whiteness. The instrument constants you obtained from the first calibration will appear with an option to edit them, but do not edit them. With the

fluorescent tile in place for measurement, allow the auto-calibration function to adjust the UV filter until the measured value satisfies a criterion. In all strictness, user calibration should always be done with a set of Hohenstein reference specimens (which have a lifetime of 90 days). Use of the fluorescent tile assumes that the Ganz-Griesser constants are indeed constant for the instrument, but a true recalibration (through "Recalibrate Parameters" in the Ganz-Griesser menu) will not make this assumption.

8. **For D65/10^{o} CIE Whiteness, how should I later use the values I first measured with the fluorescent tile?** If you are interested in paper or board under outdoor illumination, you will need the CIE Whiteness Index corresponding to Standard Illuminant D65 and 10-degree Standard Observer. In the "UV Calibration Setup" menu of Datacolor TOOLS, select "UV D65/10 (CIE whiteness)." With the fluorescent tile in place for measurement, enter the CIE D65/10 Whiteness under "Paprican" (option (b) of FAQ 5), and allow the auto-calibration function to adjust the UV filter until the measured value becomes the same as the target value. In all strictness, recalibration should be done with a Paprican paper standard using the method in ISO standard 11475. To calibrate with a Paprican standard, type the reference CIE Whiteness for that standard in the field where you would have typed the reference value for the white fluorescent tile.

9. **For C/2^{o} CIE Whiteness, how should I later use the values I first measured with the fluorescent tile?** If you are interested in paper or board under indoor illumination, you will need the CIE Whiteness Index corresponding to Standard Illuminant C and 2-degree Standard Observer. To calibrate the UV-filter setting in your instrument to C/2^{o}, choose "UV C (ISO Brightness)" in the "UV Calibration Setup". If you want to update calibration with the tile, type in the value from option (c) of FAQ 5. If not (or if you want a more rigorous calibration), then procure a Paprican reference specimen, type its ISO Brightness in the same field where the option-c value would have been entered, and perform a rigorous calibration by the method of ISO standards 11476 and 2470. After calibration, you can measure either ISO Brightness (also called R457 Brightness) or C/2^{o} CIE Whiteness with your instrument. [Note: ISO Brightness is used to set the UV filter for C/2^{o} CIE Whiteness measurements, but the two numbers are not the same. The former requires a reflectance spectrum and imposes a special blue weighting function, but the latter is computed from colorimetric x,y values.]

10. **How can I use the legacy CIE Whiteness value option (d) in FAQ 5?** The value denoted "CIE Whiteness" or "D65/10 CIE Whiteness" under Ganz-Griesser calibration is a legacy value. It was included specifically for the textile industry when the only UV calibration was Ganz-Griesser (before 2004). Use of this value is not recommended except to compare with previous uses of the index.

11. **How do I proceed if I need a new fluorescent tile?** If you lose the fluorescent tile or it is damaged, a replacement tile is available, but its reference values must be obtained on your particular spectrophotometer. To do this, order the appropriate primary-reference specimens (e.g., Hohenstein or Paprican), recalibrate your instrument with these, and record the appropriate readings on the new tile.

12. **Why do CIE and Ganz-Griesser/Hohenstein whiteness values disagree?** First, some background: Paprican, STFI, and three others manufacture reference paper specimens to be used in evaluating CIE whiteness; Hohenstein manufactures textile reference specimens to be used in evaluating Ganz-Griesser (GG) whiteness. Both CIE whiteness and GG-Hohenstein whiteness involve simulating D65 from a spectrophotometer light source by partially interposing a UV filter with a cutoff at 400 nm. In each case, the user adjusts the UV-filter setting (amount of interposition) guided by measurements of a reference specimen. Because GG and CIE have different calibration algorithms and different fluorescent agents in their reference-specimens, there is no reason to expect them to yield the same UV-filter setting. Therefore, no comparison is justified between

these standards: e.g., Paprican-CIE should be used for paper and Hohenstein-GG should be used for textiles, as intended.

13. **Is it legitimate to compare pre-2005 with post-2005 Hohenstein-based whiteness values?** One must first impose an adjustment (directed by Hohenstein) from the new whiteness value back to the old one: (W_{old} = 0,95 W_{new} + 12). That adjustment was necessitated by a re-calibration of the Hohenstein samples referenced to NRC in Canada. Going forward, whiteness values should be the new ones, but comparison with the old ones should be done with the adjustment formula. Because of this situation, Hohenstein's adjustment is not implemented in any Datacolor software; Adjustment is the responsibility of anyone seeking to compare post-2005 with pre-2005 values. Note that, prior to April 11, 2006, the GG whiteness value written on the Datacolor fluorescent tile is adjusted---i.e., "old." After that date, the reported GG whiteness value is unadjusted---i.e., "new".

14. **Is it legitimate to compare whiteness values for different instrument geometries?** Even for the same instrument model, unit-to-unit differences can occur within a tolerance of $\pm$ 2 whiteness units. Differences in instrument geometry or optics can necessitate enlarging this tolerance. Therefore, it is not advisable to compare whiteness index results from instruments with different geometries

15. **Is it legitimate to compare whiteness values for different apertures and specular-included/excluded settings on the same spectrophotometer?**
No. The calibrations made for whiteness/brightness applications must be made at the same aperture size and (for d/8 spectrophotometers) specular excluded/included setting as for subsequent measurements. For example, if a spectrophotometer is UV-calibrated at LAV, then subsequent measurements will apply only for LAV. Also, if the calibration is made specular-excluded (for d/8 geometry spectros), then subsequent measurements will apply only for specular excluded.

    The measurement conditions become more stringent if you use the calibration numbers on a certificate provided with a white-tile transfer standard (see attached specimen). In that case, the transfer-standard calibration condition of LAV (or XLAV) and specular-excluded (announced on the certificate) must be used in subsequent measurements.

    Generally, we prefer LAV and specular-excluded for UV calibration and measurement, so as to minimize the effect of sphere coloration on the measurement. Also, LAV increases the repeatability and reproducibility of the measurement. However, so long as all the measurements in a supply chain (including transfer-standard calibrations) are made with the same viewing conditions, comparisons are valid.

16. **Why can't I simply take my fluorescent tile and its Ganz-Griesser Whiteness value to another instrument?** Ganz-Griesser Whiteness measurements rely on a set of parameters that are instrument-specific. These parameters are calculated during the Ganz-Griesser absolute UV calibration with Hohenstein standards. It is significant in this regard that Ganz-Griesser calibration is done with four Hohenstein standards that have different degrees of optical brightening. That calibration determines three instrument parameters as well as the Whiteness value. If you change the instrument, you must find the instrument-parameter values using the full calibration procedure. Then you can take the Whiteness value as given.

17. **Should I expect whiteness values to be as accurate as other spectrophotometer-derived measurements?** No. Despite whiteness calibration, the method has inherently unreliable results on test specimens. This occurs partly because the D65 adjustment does not achieve a true spectral match to D65, and partly because the test specimen perturbs the color of the sphere (especially a small sphere for which the port size is an

appreciable fraction of total sphere area). Because of these factors, published tolerances of GG whiteness are large (lenient). We should live with the leniency, cognizant of the intrinsic limitations of the method.

18. **Where can I find out more about Datacolor's whiteness evaluation?** Depending on the Datacolor product you have, you can consult the "UV Calibration and Whiteness Options" chapter in either of the following manuals:
Datacolor TOOLS User Guide Part No. 4220-0927M Rev 1, April, 2005
Datacolor CHECK Manual Part No: 4230-0396M, April 2005
Both these manuals describe how to use the UV calibration feature in the relevant Datacolor product, and the use of the Datacolor product to perform whiteness evaluation.

19. **Where can I buy the primary-reference specimens?** See the following hyperlinks:

    For Paprican paper standard: www.paprican.ca
    For Hohenstein textile standard: www.hohenstein.de
    For AATCC textile standard:
    http://www.textileweb.com/Content/news/article.asp?Bucket=Article&DocID=1e93759c-e124-4f6e-b588-cd4b6f7b7d7d&VNETCOOKIE=NO

20. **Which standards apply to whiteness and brightness evaluation?** The following standards apply, some of which have been mentioned in the above FAQs:

    ASTM D985-97 Standard Test Method for Brightness of Pulp, Paper, and Paperboard (Directional Reflectance at 457 nm) see www.astm.org .
    ASTM E313-05 Standard Practice for Calculating Yellowness and Whiteness Indices from Instrumentally Measured Color Coordinates; see www.astm.org .
    TAPPI T-534 om 92 Brightness of clay and other mineral products (d/o diffuse); see www.tappi.org .
    TAPPI TIS 0804-05: Indices for whiteness, yellowness, blue reflectance factor and luminous (green) reflectance factor; see www.tappi.org .
    ISO 11475: 1999 Paper and board---Determination of CIE whiteness, D65/10^{o} (outdoor daylight); see www.iso.org .
    ISO 11476: 2000 Paper and board---Determination of CIE whiteness, C/2^{o} (indoor illumination conditions)
    ISO 2470: 1999E Paper, board and pulps---Measurement of diffuse blue reflectance factor (ISO brightness); see www.iso.org .
    AATCC Test Method 110: 2005 Whiteness of Textiles; see www.aatcc.org .