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Evaluation of Available ISO 13655 Backing Materials and Measurement Differences for the Packaging Industry

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Abstract

Annex A of ISO (International Standard Organization) 13655 defines specimen backing requirements used for the measurement of color in the graphic arts industry. Due to the varying aspects of print processes, different vendors and print manufacturers are using various backing substrates for color calibration or measurements.

This study is aimed to discover and evaluate backing products available on the market based on the ISO requirements, including those officially recognized backing materials as well as materials designed for other purposes but could be used as ISO compliant backing. The results identify some cost-efficient surface materials that are feasible for packaging suppliers as well as the graphic arts industry.

Introduction

Backing materials are commonly used whenever a densitometric or colorimetric measurement is needed. Most of the printing inks and substrates used in flexible package printing are not fully opaque, therefore, the characteristics of the backing underneath the print specimens will influence the measured spectral reflectance data. As ISO 13655 (2017) describes, the significance of backing in terms of print specimen measurement can be correlated to the opacity of the inks and substrate. This effect can be frequently observed from the flexographically printed clear PET film, where an opaque white ink is printed first to not only hide the content of a packaged product but also to boost the color appearance of the printed color and design. This white ink serves a similar purpose as a standardized white backing material. The method of controlling white ink laydown is outside the scope of this paper.

To achieve and maintain a high level of consistency of measurement, some spectrophotometers have an integrated backing surface or plate in the measurement system. Some examples are the TECHKON SpectroVision in-line spectrophotometer that comes with an industrially painted white plate to comply with the ISO 13655 requirements and with high stability to endure pressroom conditions and the X-Rite i1iO table which has a white flat surface to provide backing for its i1Pro devices. Since the aforementioned backings are both proprietary items that cannot be purchased separately, the researcher is determined to collect some potential substitutes that are available in the current market and evaluate their compliance level with the requirements offered by the ISO 13655 Annex A standard.

For this study, a total of thirty-three specimens were collected from various manufacturers with different application purposes. Due to the lack of products that are dedicated to backing purposes, only three backing materials are available to the researcher by the time of sample collection. The rest of the thirty specimens were introduced to this study based on the proof substrate list certified by Fogra and the field survey. Each specimen was tested against the requirements listed in the ISO 13655 for either standard black backing or standard white backing.

Design of Experiment

The ISO 13655 (2017) defines the requirements for both the standard black backing and the standard white backing. According to this document, a standard white backing shall be used if the specimens being measured by reflection are transparent. For other specimens, the readers are recommended to follow the guidance provided by standards such as ISO 12647 series for process control. The ISO 13655 Annex A also provides a linear conversion based on CIE tristimulus XYZ value for readers that wish to compare measured data on certain backing (black or white) to an absolute reference value.

Due to the differences in requirements for standard black backing and standard white backing, this paper will review each item and its evaluation steps separately.

Standard Black Backing
For the standard black backing, the ISO 13655 Annex A shares the same required properties written in the ISO 5-4 standard, which are listed below.

- Spectrally non-selective;
- It should be diffusely reflecting;
- Opaque substrate;
- Minimum ISO 5 visual reflection density of 1.30;
- Maximum ISO 5 visual reflection density of 1.60.

Testing Methodologies:
- Spectrally non-selective

When a white light impinges on an object, the color appearance of such an object results from its spectral reflectance factor. The pigment or dye contained in an object determines the wavelength and magnitude of the visible light spectrum wavelengths that are absorbed and the rest is scattered back to the observer or photoreceptor. Figure 1 below depicts the spectral reflectance curves of a white ink and a red apple. The red apple reflects more light in the long-wavelength spectrum; thus, it appears to be red in observation. While the white ink reflects a similar amount of light across the visible spectrum, therefore it has a neutral appearance. For an object that absorbs or reflects similar amounts of wavelength across the visible spectrum from 400 nm to 700 nm within a defined control limit, it is considered as spectrally non-selective.

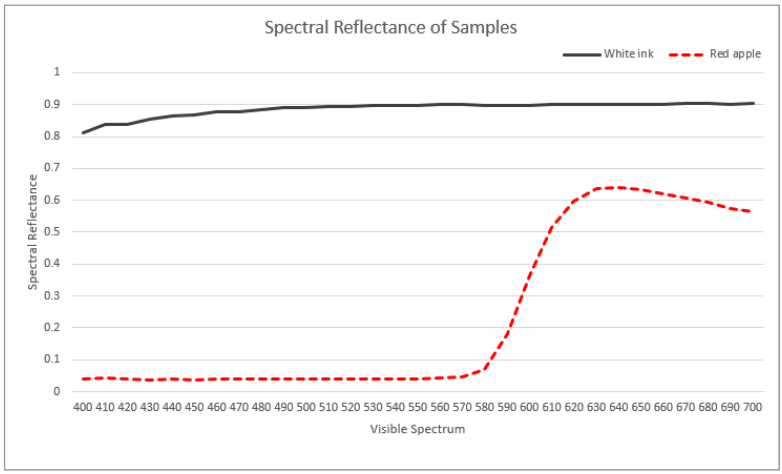

Figure 1. Spectral reflectance curve of a white ink and red apple.

The ISO 13655 Annex A indicates an ideal method to define the control limit is that the total range of spectral diffuse reflection density throughout the wavelength interval from 400 nm to 700 nm does not exceed 5 % of the average density obtained over the same interval.

After capturing the reflectance of a specimen from 400 nm to 700 nm, its spectral diffuse reflection density can be calculated using the method described in ISO 5-3 (2009) as shown below.

$$Reflection\ Density(D) = -\log_{10}\left[\frac{\sum_{400}^{700}(R_\lambda \times W_\lambda)}{\sum_{400}^{700} W_\lambda}\right]$$

where

R is the spectral reflectance factor at wavelength λ;
W is the spectral product at wavelength λ.

Once the spectral reflection density is calculated, we can compare spectral densities at each wavelength with the control limit, which is 5 % of the reflection density to verify if such a specimen is spectrally non-selective.

1		400	410	420
2	BB Input 1	0.0381	0.0403	0.0411
3	BB Input 2	0.0386	0.0408	0.0422
4	BB Input 3	0.0379	0.0397	0.0406
5	Average Reflectance - R	0.0382	0.040267	0.0413
6	Spectral product - w (ISO T)	0.000016	0.000019	7.8E-05
7	R x w	6.112E-07	7.65E-07	3.2E-06
8	Sum_Rxw	0.036117233		
9	Sum_w	1.000002		
10	Reflection Density	1.442286393		
11	Indiv. D	1.417936637	1.395054	1.38405
12	Range	0.062471584		
13	Avg D.	1.43328719		
14	5% of Avg D.	0.071664359		
15	Pass	1		
16	* Yes -1, No - 0			

Figure 2. Each specimen was spectrally averaged to calculate its spectral densities per 10 nm and compared to 5 % of its average density

- Diffusely reflecting

The ISO 8254-75° gloss meter is recommended to use in the ISO 13655 Annex A to check the gloss level of a standard black backing to be lower than 40 Gloss Unit (GU). Moreover, it also states that the same tolerance can be used with a gloss meter with angles of 60° or 85° for inks and coatings application. In this study, a gloss meter with 60° geometry was utilized.

- Opaque substrate

Since there is no clear definition in ISO 13655 on how to qualify a substate to be considered as opaque, the researcher follows the suggestion described in the ISO 5-4 that one whose own reflection density does not depend on the presence of or type of backing material used in its measurement.

To test the opacity of standard black backing, the researcher captured the densities of each specimen using self-backing as well as a white backing from Leneta (form N2C-3). As long as the averaged white-backing-density lies within the variation of densities measured with the specimen's self-backing, this specimen is deemed as opaque.

- ISO 5 visual reflection density between 1.30 to 1.60

The TECHKON SpectroDens has a built-in density mode to display visual reflection density after each measurement. All black specimens were measured and recorded for comparisons.

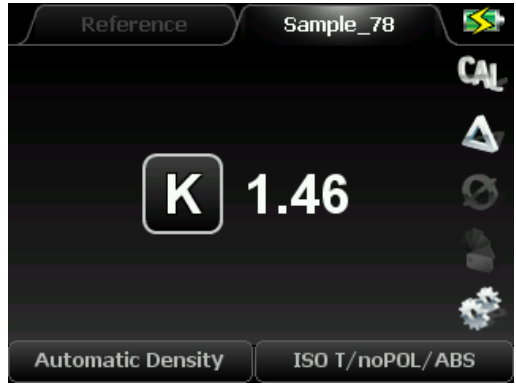

Figure 3. Visual reflection density of a black specimen recorded by TECHKON SpectroDens device

Standard White Backing

Similar to the standard black backing, the ISO 13655 Annex A also lists the following requirements for the standard white backing.

- It shall be opaque. The opacity shall be equal to or greater than 99;
- It should be diffusely reflecting;
- It's CIELAB C* value shall not exceed 3 and should not exceed 2.4;
- It shall be non-fluorescing
- The spectral reflectance factor values shall lie within the curves given in Table A.1.

Test Methodologies:

- It shall be opaque

Unlike the standard black backing, the ISO 13655 specifies how the opacity should be evaluated for the standard white backing shown below:

$$O_B = (Y_b/Y_w) \times 100$$

where

O_B is opacity (0°:45°, D50, 2°, Y) of the backing material;
Y_b is the CIE Y value computed from measurements made using black backing conforming above;
Y_w is the CIE Y value computed from measurements made using a stack of at least three sheets of the material to be used for backing.

The opacity equation used by ISO 13655 is adopted by the Opacity function on the TECHKON SpectroDens device, which was used to measure each white specimen in this test. The standard black backing used here is the Leneta N2C-3.

- It shall be diffusely reflecting

The same testing methodology was used as described in standard black backing.

- It's CIELAB C* value shall not exceed 3 and should not exceed 2.4

Unlike the CIELAB color space uses a cartesian coordinate system to define individual colors, the CIELCh color scale, which is calculated from the CIELAB scale values shown below, uses a cylindrical coordinate system. The CIELAB C* represents Chroma and the higher value it gets, the stronger or more vivid the color is.

$$CIE\ C^* = \sqrt{a^{*2} + b^{*2}}$$

- It shall be non-fluorescing

The Fluorescent Whitening Agents (FWA) or Optical Brightening Agent (OBA) is commonly added during the papermaking process to improve the visual perceived brightness/whiteness of the substrate. Under illuminants with UV, such as D50, D65, or fluorescing lighting, paper with an OBA component usually has emission in the short wavelength of the visible spectrum and sometimes has a total radiance factor exceeding 100% over the same area. A fairly easy test to check the OBA contained in the paper as suggested in ISO 15397 is, the difference of the CIE b* values between M1 and M2 measuring conditions indicates the degree of fluorescence that can be expected in graphic arts viewing and measurements. While, for the consistency of this research, the method listed in ISO 13655 Annex A, quoted below, was carried out for evaluating the fluorescence of white backing specimens.

"…This is equivalent to reading the backing sheet with M1 and M2 modes and the differences at any wavelengths greater than 410nm shall be less than or equal to 3σ (3 standard deviations) of 5 readings of the backing sheet using only the M2 mode."

Once measurements with both M1 and M2 modes are recorded for each specimen, the standard deviations were calculated from 410 nm to 700 nm with a 10 nm interval. Figure 4 illustrates the spectral reflectance curves of a qualified white backing specimen and its control limit range.

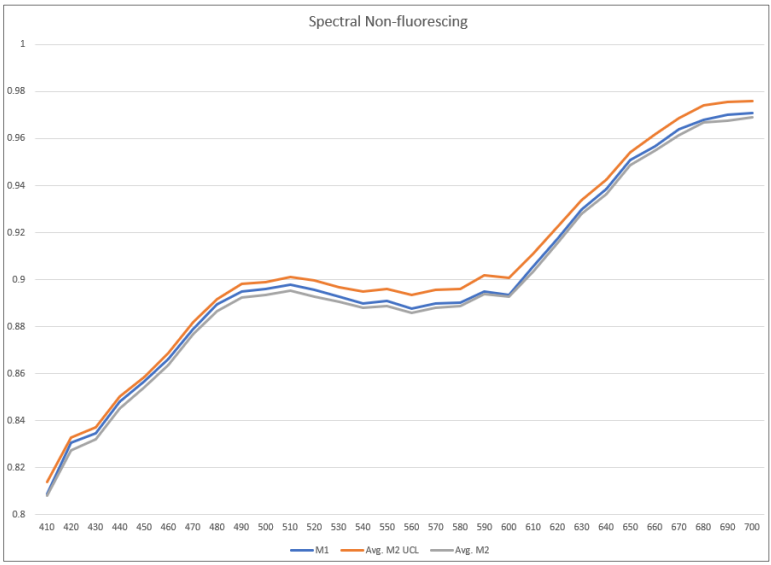

Figure 4. Spectral reflectance curves of a qualified white backing specimen under M1 and M2 mode with an upper control limit of 3σ shown in orange

- The spectral reflectance factor values shall lie within the range of the curves given in Table 1.

After plotting the lower and upper control limits, the spectral reflectance curve of each white backing specimen was visualized to compare its compliance as Figure 5 shows.

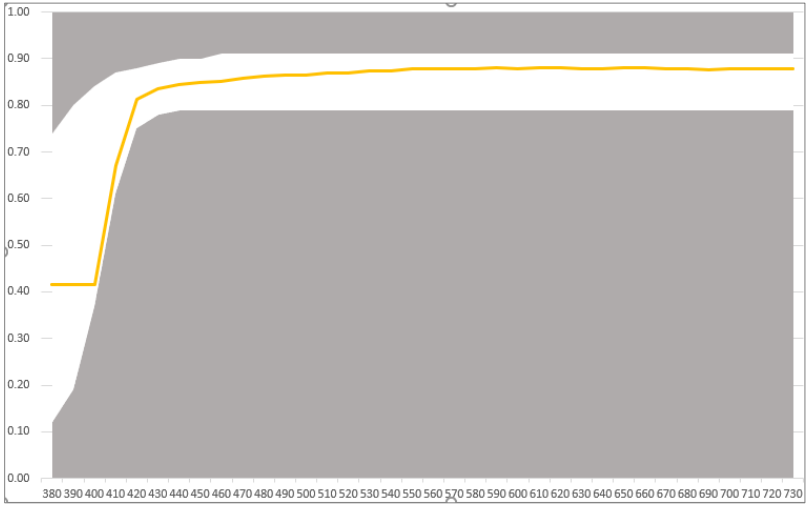

Figure 5. Spectral reflectance range with upper & lower limit

Table 1 – Spectral reflectance factor

Wavelength	Spectral reflectance factors	
nm	Upper limit	Lower limit
380	0.74	0.12
390	0.80	0.19
400	0.84	0.37
410	0.87	0.61
420	0.88	0.75
430	0.89	0.78
440	0.90	0.79
450	0.90	0.79
460	0.91	0.79
470	0.91	0.79
480	0.91	0.79
490	0.91	0.79
500	0.91	0.79
510	0.91	0.79
520	0.91	0.79
530	0.91	0.79
540	0.91	0.79
550	0.91	0.79
560	0.91	0.79
570	0.91	0.79
580	0.91	0.79
590	0.91	0.79
600	0.91	0.79
610	0.91	0.79
620	0.91	0.79
630	0.91	0.79
640	0.91	0.79
650	0.91	0.79
660	0.91	0.79
670	0.91	0.79
680	0.91	0.79
690	0.91	0.79
700	0.91	0.79
710	0.91	0.79
720	0.91	0.79
730	0.91	0.79

Measurement device

- TECHKON SpectroDens 4
- 3NH YG60S 60° Gloss Meter

Software

- TECHKON SpectroConnect 2.8.0.3
- Microsoft Excel 2016

Backing specimens

Table 2 – Black backing specimens

Black backing	
Category	Specimen
Leneta Contrast Card	N2C-3 Opacity
	3NT-1 Ink Test
	3NT-35 Ink Test
	3NT-41 Ink Test
	3B Opacity
Munsell	ISO Backer
ChromaChecker	Substrate Inspector Backer
	Measurement Backer
Paint Chip	Marquee Black G9-7
	Marquee Limousine Leather MQ5-05
	Marquee Private Black N530-7
	Olympic Black Magic OL116 N6
	Sherwin Williams Tricorn Black HGSW1441
	Martha Stewart Silhouette MSL280
	Behr Blackout N510-7
	Gliden Onyx Black GLN62

Table 3 – White backing specimens

White backing	
Category	Specimen
Leneta Contrast Card	N2C-3 Opacity
	3NT-1 Ink Test
	3NT-35 Ink Test
	3NT-41 Ink Test
	3B Opacity
Munsell	ISO Backer
ChromaChecker	Substrate Inspector Backer
	Measurement Backer
Paint Chip	Valspar Ceiling Paint
	Valspar Woodlawn Dewkist 7004-11
	Valspar Bleached Slate 7004-20
	Behr Silky White PPU7-12U
	Behr Frost 57U
	Behr Gallery White PPU12-12U

	PPG Snow Storm 1172-1
	PPG Commercial White 1025-1
Proofing Stocks	CGS PearlProof Super
	CGS PearlProof Super Glossy
	CGS PearlProof Super V
	CGS PearlProof Super V NEU
	Legion Semi_Matte 195 GSM
	Legion Semi_Matte 240 GSM
	Cromanet UltraPlus SM
	Cromanet UltraPlus GL
	Anonymous Semi_Matte

Result and Discussion

Among all the specimen categories, the Leneta card and the proofing stock are probably most commonly seen in the field as measurement backing. During this study, the average cost for the Leneta card is in the range of $0.07 to $0.35 per sheet depends on the actual form we are getting. Besides the cost-benefit, some of the Leneta card forms, such as the 3B, provide decent black (average spectral reflectance value under 1%) and white surface contrast, which is crucial when measuring opacity, as well as decent durability for a production environment. Similarly, the proofing stocks are quite popular as white backing for the same reasons.

The Munsell and ChromaChecker specimens are included as products deliberately developed to be used for backing purposes. The Munsell specimen, or PantoneLive Backing Material with part number PLV-N925, is an ISO 13655 compliant white backing card that can be ordered by contacting a dealer. Unfortunately, the author was not able to find its pricing information at the time of the experiment. As for the two products from ChromaChecker, the Measurement Backer comes with two sizes: 11x17 inches at the cost of $125 and 2.75x2.75 inches at the cost of $15.

The paint chips used in this study were collected from nationwide hardware chain stores, such as Home Depot and Lowe's, and are considered good candidates for the research due to merits like low cost (free chips or $22 to $45 per gallon for painting), easy to obtain and versatile selection of gloss finish.

After measurements were taken from each specimen, the table below shows the result for standard black backing and standard white backing respectively.

Table 4 – Standard Black Backing Compliance

Black backing				
	Spectrally non-selective	Diffusely reflective	Opaque	Density between 1.3 to 1.6
N2C-3 Opacity	✓	✓	✓	✓
3NT-1 Ink Test	✗	✓	✗	✓
3NT-35 Ink Test	✗	✓	✓	✗
3NT-41 Ink Test	✗	✓	✗	✗
3B Opacity	✓	✓	✓	✗
ISO Backer	✗	✓	✓	✓
Substrate Inspector Backer	✓	✓	✓	✓
Measurement Backer	✗	✓	✓	✗
Marquee Black G9-7	✓	✓	✓	✓
Marquee Limousine Leather MQ5-05	✓	✓	✓	✓
Marquee Private Black N530-7	✓	✓	✓	✓
Olympic Black Magic OL116 N6	✓	✓	✓	✓
Sherwin Williams Tricorn Black HGSW1441	✓	✓	✓	✓
Martha Stewart Silhouette MSL280	✓	✓	✓	✓
Behr Blackout N510-7	✓	✓	✓	✓
Gliden Onyx Black GLN62	✓	✓	✓	✗

Table 5 – Standard White Backing Compliance

White backing					
	Opaque	Diffusely reflective	CIE C* < 3	Non-fluorescing	Spectral reflectance factor within the range
N2C-3 Opacity	✓	✓	✓	✓	✗
3NT-1 Ink Test	✗	✓	✗	✓	✓
3NT-35 Ink Test	✗	✓	✓	✗	✗
3NT-41 Ink Test	✗	✓	✗	✓	✗

3B Opacity	✓	✗	✗	✓	✗
ISO Backer	✓	✓	✓	✓	✓
Substrate Inspector Backer	✓	✓	✓	✗	✗
Measurement Backer	✓	✓	✓	✓	✓
ORIS Super	✗	✓	✓	✓	✗
ORIS Super Glossy	✗	✗	✓	✗	✗
ORIS Super V	✗	✓	✓	✗	✗
ORIS Super V NEU	✗	✓	✓	✓	✗
Moab 195 GSM	✗	✓	✓	✓	✗
Moab 240 GSM	✗	✓	✓	✗	✗
UltraPlus SM	✗	✓	✓	✓	✗
UltraPlus GL	✗	✓	✓	✗	✗
Anonymous	✗	✓	✓	✗	✗
Valspar Ceiling Paint	✓	✓	✓	✓	✓
Valspar 7004-11	✓	✓	✓	✓	✓
Valspar 7004-20	✓	✓	✓	✓	✓
Behr PPU7-12U	✓	✓	✗	✗	✓
Behr Frost 57U	✓	✓	✓	✓	✓
Behr PPU12-12U	✓	✓	✓	✓	✓
PPG 1172-1	✓	✓	✓	✓	✗
PPG 1025-1	✓	✓	✓	✓	✓

Note: All paint specimens are considered opaque by default based on their application

In summary, the paint chips did exceptionally well with 7 out of 8 specimens meeting all criteria as standard black backing, and 6 out of 8 specimens qualified as standard white backing. Meanwhile, the Leneta N2C-3 card and ChromaChecker' s Substrate Inspector Backer were tested as compliant standard black backing; the Munsell ISO backer and ChromaChecker' s Measurement Backer can be claimed to be used as standard white backing. On the contrary, none of the proofing stocks in this study were able to satisfy every requirement as mandated by ISO 13655.

To understand the difference between paint chips and actual formulated paint, the researcher selected two paint chips, Marquee Limousine Leather MQ5-05 and Behr Frost 57U, and ordered their formulated fresh paints from the Home Depot with a 0.25" nap roller and white melamine board. After applying one coat of each paint on the melamine board and letting it dry for 72 hours, measurements were taken to evaluate their compliance per ISO 13655. The result shows a good alignment between the paint chip and the formulated paint product. Therefore, the paint seems to be a good solution to ISO compliant backer due to their availability and cost with a few assumptions: 1) The paint technician that formulates the paint based on paint chips needs

to be consistent and accurate. 2)Since the matte paint surface is prone to ink smudge, scratch, and other wear-and-tear, some routine maintenances are required such as surface retouching.

Conclusions

In this study, 16 black backing and 26 white backing specimens were evaluated for conformance to ISO 13655. Here are the key take-aways:

- Of all the materials, 9 black specimens were found to be compliant and 8 white specimens were found to be compliant.
- There are 5 officially recognized compliant backing materials that have both white and black surfaces for measurement backing. They accounted for 31% of total white specimens and 19% of total black specimens tested in the research. The result shows only 1 out of 5 materials can be used as ISO 13655 compliant standard blacking backing and 2 out of 5 for standard white backing.
- Comparing to other compliant materials, the officially recognized compliant backings were found to be quite expensive
- Many of the compliant materials were produced using commercially available home decorating wall paints which are much less expensive and readily available.

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