What is ISO brightness?

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ABSTRACT: The introduction of modern instruments and new products, particularly those containing fluorescent whitening agents, has created situations where the term "ISO brightness" may become ambiguous. Thus it is important to clarify what ISO brightness is and what it is not.

KEYWORDS: Brightness, fluorescence, illumination, instrumentation, ISO, measurement, whiteness.

The concept of brightness is well established as a way of describing the optical properties of pulp and paper, but the development of modern instruments and new products, particularly those containing fluorescent whitening agents (FWAs), has led to a situation in which there are signs that the term is becoming increasingly ambiguous. It is therefore necessary either (a) to restrict the use of the term ISO brightness to materials not containing fluorescent or photochromic components, or (b) to define ISO brightness strictly as a measurement made with little or no UV radiation in the measurement illumination, and to introduce additional concepts such as D65 brightness or whiteness, indoor brightness or whiteness, and a basic (nonfluorescent) substrate brightness or whiteness to permit a fuller description of those papers which contain fluorescent whitening agents.

Since the first alternative is unrealistic and not in keeping with the traditional brightness concept, the second alternative is here strongly advocated. This brings into focus the question of "brightness" or "whiteness," but this article is concerned primarily with the need to introduce some degree of clarity into the current situation with regard to the concept of brightness. It refers briefly to the issue of whiteness determination as an alternative or a complement to a brightness measurement, but it leaves details of the measurement of whiteness to a future article.

ISO brightness

ISO brightness is a 15-year-old concept which is familiar to most people in the pulp and paper fields. To many persons working regularly with the measurement and reporting of brightness, it may therefore seem strange to ask what it is and to suggest that it is ill-defined. There is, nevertheless, a growing ambiguity—not in the pulp field, where the concept is still fairly well defined and understood, but rather in the paper field, where the use of fluorescent whitening agents coupled with the availability of different instruments unfortunately introduces both conceptual difficulties and measurement complications.

There are, however, one or two things which can be said initially to clarify what ISO brightness is and what it is not. We hope this will help to eliminate one or two misunderstandings and clear the way toward a more stringent regard for the brightness concept.

ISO brightness received its name from the International Standardization Organization. When the International Standard ISO 2470 *(1)* was first published, it was necessary to differentiate between this property, measured with a diffuse illumination (d/0°), as in the Elrepho instrument, and data obtained using a directional illumination (45°/0°), as in the GE instrument. The results of optical measurements are sensitive to the geometry of illumination and viewing, and there is a need to distinguish between these two types of measurement and to report clearly which method has been used. This article is not, however, concerned with the differences between or the merits of these two systems. It is devoted solely to the need for a more rigorous attention to the fundamental features of the diffuse ISO brightness.

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Visual significance

In the first place, it should be noted that:

- ISO brightness is essentially useful as an arbitrary but sensitive measure of the progress of bleaching in a bleaching plant.
- ISO brightness is not a direct measure of any visual property. It is not related to any system of colorimetric measurement, and it has no foundation in perceptual psychology.

Type of instrument

In the second place, it should be noted that the instrumental conditions of measurement are rigidly defined:

- ISO brightness is a measurement made in a specific type of apparatus having a 150-mm sphere providing a diffuse illumination and fitted with a large gloss trap to eliminate all specular reflection into the receptor. The detector is placed so that the sample is viewed normally, i.e., at an angle of 0° to the perpendicular to the plane of the sample. This type of instrument is carefully defined in ISO 2469 *(2)*, which is the basic standard on which ISO 2470 *(1)* and ISO 3688 *(3)* are based. The definition of ISO brightness also requires that the apparatus be calibrated in accordance with the procedure outlined in ISO 2469. If the instrument is calibrated in any other way, ISO brightness cannot be measured.
- ISO brightness is not a measurement made in some other type of apparatus to which some sort of polynomial regression has been fitted in order to provide data which correlate well with data measured on a true ISO 2469 instrument. Any attempt to declare an ISO brightness value based on the use of such a nonstandard instrument is basically a falsehood, although the attempt to fit a correlation may be well meaning.
- ISO brightness is not a measurement made in an instrument in which the illumination is directional at an angle of 45° to the normal and the viewing is normal (0°). Such instruments, which measure a property often known as GE brightness or TAPPI brightness, give a value which normally does not differ from ISO brightness by more than a couple of brightness units, but there is no method of conversion from one geometry to the other.

Wavelength distribution

In the third place, it can be pointed out that:

- ISO brightness is a value measured with a fairly broad filter or calculated with the help of a mathematical function having an effective wavelength of 457 nm and a bandwidth of 44 nm. In this respect, it is defined in the same way as the directional TAPPI brightness.
- ISO brightness is not a monochromatic assessment of the reflectivity of a material at a single wavelength of 457 nm.

Ambiguity of the brightness concept

The original version of ISO 2469 referred essentially to the now obsolescent Zeiss Elrepho reflectometer as the only instrument which then conformed to the standard, and ISO brightness was then a fairly unambiguous concept. Currently, however, there are several other types of instruments *(4)* which conform to the requirements of ISO 2469. To understand a brightness value, it is now necessary to ask, "With what instrument and with what filter?" This means that the term brightness is no longer satisfactory. The fault lies not, however, in the instruments, but in the lack of stringency with which the property is defined and in the lack of accuracy with which its measurement is standardized in relation to the wider scope and greater flexibility of modern instruments.

For many materials, there is no problem since they are not physically sensitive to the actual light source in the instrument, and the values calculated from measurements in a properly calibrated instrument are independent of the type of lamp used. The trouble arises when materials are fluorescent or photochromic, which means that they are indeed physically sensitive to the actual energy distribution of the light with which they are irradiated.

This factor was realized several decades ago, when the ISO method for brightness determination was last revised. At that time, it was stated in the text that, if fluorescent whitening agents (FWAs) are present, this method should be used only with caution since different instruments can then give different results. This was, however, still written at a time when the Zeiss Elrepho was the only instrument available. The possible variations referred to were only those due to differences in the UV content of different lamps and to differences between different spheres in different instruments of the same type.

At the present time, however, the difference is potentially much greater in the wider range of instruments conforming to ISO 2469 on the market. The Technidyne instruments and the Datacolor Elrepho 2000, for instance, have very different light sources, and in this respect, if FWAs are present, a mathematical calibration is inadequate—the light source needs to be controlled.

This introduces another problem because ISO brightness is defined in terms of mathematical weighting functions with no reference to any light source. The Scandinavian standard for the measurement of ISO brightness, SCAN-P3 *(5)*, recognizes this deficiency, however, and points out that the radiometric characteristics of the lamps used in the Zeiss Elrepho instrument (which was the definitive instrument when ISO 2469 was written) are close to those of the A-illuminant. Although the C-illuminant is the standard for most optical measurements on paper, no instrument has ever had a lamp corresponding to the C-illuminant. The conversion from A to C in the Elrepho and Technidyne instruments, for instance, is achieved by a filter in the reflected beam and not by any adjustment of the incident light.

At its meeting in Rotorua 1991, ISO/TC6/WG3 desired it to be understood that, although the light source was never defined in the ISO standards, the concept of ISO brightness is historically linked to an instrument having a source corresponding clearly to the A-illuminant. It is thus only when the light source matches this illuminant that the conditions for the measurement of ISO brightness are fulfilled.

Conditions for the measurement of ISO brightness

If it is agreed that ISO brightness is a property which is measured in the older Zeiss Elrepho instrument, then it is clear that, for materials which are fluorescent or photochromic, the Technidyne instrument with its tungsten halogen lamp is acceptable, but the unfiltered radiation from the xenon flash lamps in the Datacolor E2000 instrument is not acceptable.

The problem has not been finally solved, but it has been empirically established that fairly good agreement with the older Zeiss Elrepho can be achieved in the Datacolor instrument if a GG395/3 filter, which eliminates most of the UV radiation, is introduced into the path of the incident light. To use this setting of the filter to eliminate most of the UV component of the illumination is currently the best recommendation which can be given if ISO brightness is to be measured. This is not, however, an exact adjustment, and it is still true that the method should be used only with caution if FWAs are present since different instruments give different results. Part of the difficulty lies in the fact that there is a certain degree of excitation of the fluorescence even with the type of incandescent lamp used in the older Zeiss Elrepho instruments and that the FWAs are sensitive not only to UV radiation but also to a part of the visible radiation, up to a wavelength of approximately 420 nm.

Alternative brightness measurements

Since FWAs are added in order to increase the appearance of whiteness of the product, it is naturally desirable to characterize these products by measuring a property which takes account of the presence of these agents. Some sort of measurement using an illumination having a high UV content is obviously desirable. Indeed, the incorporation of xenon flash lamps into the Datacolor E2000 instrument was motivated by the fact that attempts had already been made to incorporate a xenon lamp accessory into the Zeiss Elrepho and to introduce the concept of Z brightness *(6)*.

Current thought favors the use of the D65 illuminant, which has a defined distribution in the UV region, in order to measure a property which, to avoid confusion with ISO brightness, should be designated D65 brightness. The only reasonable approach appears to be to calculate such a D65 brightness using the same weighting functions as those applicable to ISO brightness and to disregard subtle attempts to determine what weighting function coefficients would correspond to the situation if the ISO brightness filter were used in the old Zeiss Elrepho instrument with a xenon lamp attachment.

There is, however, especially in Europe and Australia, an interest in complementing the measurement of brightness with a measurement of CIE whiteness *(7)* defined for the D65 illuminant and the CIE-1964 standard observer. This parameter gives a more reliable indication of the whiteness of the product since it takes into consideration the reflectivity of the material over the whole visual region, and it has a basis in perceptual psychometric studies of the visual assessment of whiteness.

In addition, there is a body of opinion, particularly in North America but also in Europe, in favor of defining an indoor illuminant to permit the standardized measurement of an indoor brightness/whiteness property. It has been pointed out that paper grades for which brightness or whiteness is a useful property are usually bought, sold, and used in an indoor environment. Work is in progress in this direction within ISO/TC6/WG3 and also within the programs of similar national committees.

Instrument calibration

If such properties are accepted and rigidly defined, it is still true that different instruments may give different results unless an elaborate system of calibration and adjustment is introduced. The basis of such a calibration system has already been created by ISO/TC6 in accordance with ISO 4094 *(8)* and is described in ISO 2469, but this system provides only a photometric calibration using nonfluorescent reference standards and is not concerned with the radiometric adjustment of the illumination. An extension of this system is necessary to include either a fluorescence calibration or a routine for the adjustment of the UV content of the illumination.

An earlier proposal *(6)* for a method of measurement based on the concept of Z brightness has now been withdrawn, largely because the calibration system envisaged could not be implemented, and it thus merits no further comment.

A system for adjustment of the illumination based on sets of fluorescent cotton samples has been developed by the Hohenstein Institute in Germany based on earlier work at Ciba-Geigy in Basel, Switzerland. More recently, however, a system has been developed at STFI in Stockholm based on absolute measurements made on fluorescent paper samples at BAM *(9)* in Berlin. These fluorescent reference standards permit the adjustment of the illumination so that the excitation of fluorescence in the reference standard in the instrument concerned corresponds to that which would be excited by a true D65 source.

It is characteristic of both these methods that they involve calibration based on a whiteness measurement and not on brightness, because current interest has been centered on the development of routines for standardized whiteness measurement and also because, in contrast to the situation with the D65 brightness function, the whiteness function is rigorously and unambiguously defined.

The use of such standards is currently the only way of adjusting different instruments to a level of illumination on the sample corresponding to the D65 illuminant, whether it be desired to measure D65 brightness or CIE whiteness. The reproducibility of a D65 brightness measurement on different instruments adjusted in this way may not be as good as that of the CIE whiteness (D65) measurement, but the variation is much less than that achieved by other methods.

A discrepancy between the levels given by the two calibration procedures derived from Ciba-Geigy/Hohenstein and BAM/STFI is currently being investigated. The use of different transfer materials may be one reason for the discrepancy. For many reasons, there appear to be advantages in calibrating the instrument using paper transfer standards if the product to be measured is also paper. A number of different types of fluorescent tablets which serve as admirable stable working standards for checking the UV content of the illumination are, however, now appearing on the market.

Brightness or whiteness?

Within the paper sector, there is a clear interest in augmenting the concept of brightness and introducing as a product specification the concept of whiteness. It has long been realized that brightness is an inadequate measure of the visual appearance of a material, since the measurement of this property takes place within a restricted region at the blue end of the spectrum. The CIE-whiteness value, which is based on reflectance data for the whole of the visible spectrum, is a value which more closely corresponds to the visible appearance of the material and is also easier to complement with a tint measurement and other colorimetric parameters.

It was time-consuming to make such measurements with the Zeiss Elrepho because it was necessary to make separate measurements with three different filters and to make an intermediate calibration each time a filter was changed. In the modern instruments, however, whiteness can easily be determined since all the necessary measurements are made in a single operation.

The fluorescence component

It is no secret that high D65 brightness/whiteness in paper is often achieved by the use of FWAs. This means that it is often necessary to be able to measure the degree to which the FWA contributes to the brightness or whiteness, from the point of view of both product description and process control. This desire to be able to measure the characteristics of the substrate if no FWA were present, or the desire to determine whether in fact any FWA is present, is probably easier to meet if the interest in brightness is converted to an interest in whiteness. Here it suffices to emphasize that in order to eliminate all traces of fluorescence, it is necessary to introduce a filter with a cutoff in the region of 420 nm. An L420 filter is incorporated in the Technidyne TB-1C instrument. A GG420/3 filter should be used in the case of the Datacolor Elrepho 2000.

Since this filter cuts off all radiation below 420 nm and thus encroaches upon the visible region and partially intersects the working region of the brightness function, problems may arise in the measurement of brightness. It appears that these problems may not affect the calculated whiteness value to the same degree, but the important fact to note is that in order to achieve reproducibility and to permit the true measurement of the optical properties in the absence of any FWA, a cutoff filter operating at 420 nm is essential.

Conclusion

To avoid unnecessary ambiguity, the measurement of brightness and whiteness requires a general understanding of and agreement concerning the following points.

- The concept of ISO brightness is historically linked to an instrument having a source corresponding closely to the A-illuminant. In instruments of the Datacolor E2000 type, the conditions for the measurement of ISO brightness are approximately fulfilled if a GG935/3-mm filter is introduced into the light beam.
- If an instrument is adjusted with the help of suitable reference standards so that the illumination reaching the sample corresponds to the D65 illuminant, the D65 brightness of the sample can be measured. If the paper contains no FWA, the D65 brightness and ISO brightness values are identical. When FWAs are present, the

measurement of brightness without adjustment of the light source to correspond to the D65 illuminant is meaningless.

- Fluorescent reference standards are now available to permit the adjustment of the illumination to conform to the D65 illuminant. These are based on a CIE (D65/10°) whiteness level.
- The fluorescence contribution can be established by first making a measurement with the illumination adjusted to match the D65 illuminant and then making a new measurement with a cutoff filter at 420 nm to eliminate the fluorescence effect associated with the FWA. The trend appears to be towards measuring a difference in CIE whiteness rather than a difference in brightness. This type of measurement provides a characterization of the substrate material and also a basis for the measurement of residual fluorescence in nominally fluorescence-free products.

Literature cited

1. ISO 2470, Paper and board—Measurement of diffuse blue reflectance factor (ISO brightness).
2. ISO 2469, Paper, board and pulps—Measurement of diffuse reflectance factor.
3. ISO 3688, Pulps—Measurement of diffuse blue reflectance factor (ISO brightness).
4. Instruments conforming to ISO 2469 currently are the Datacolor Elrepho 2000; the Technidyne TB-1C and micro-TB-1C; and the Color Sensors Oy AutoElrepho.
5. SCAN-P3, Pulps, paper and boards—ISO brightness.
6. ISO-DIS 7856, Paper and board—Determination of diffuse Z reflectance factor of fluorescent white materials (Z brightness).
7. CIE: Commission Internationale d'Eclairage.
8. ISO 4094, Paper, board and pulps—International calibration of testing apparatus—Nomination and acceptance of standardizing and authorized laboratories.
9. BAM: Bundesanstalt für Materialforschung und -prüfung, Berlin.

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