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Indices for whiteness, yellowness, brightness, and luminous reflectance factor

1. Scope

This Standard Practice deals only with simplified color indices applicable specifically to white colors. There are approximately 5000 distinguishable white colors. As with any other color, three numbers are necessary for the complete identification of any white. All the color and color difference scales regularly used for color specification are applicable to white colors.

2. Significance

2.1 White is the color of purity or freshness and of cleanness. The consumer judges the whitest shirt to be the freshest and cleanest and automatically selects it from several on display. In some products, whiteness is not only psychologically associated with purity, but is actually an indicator of freedom from contaminants, and as such can be a measure of the quality of the product. Good white base colors are necessary where products are to be dyed, printed, or otherwise colored. The cleanness, brightness, and full range of color in color printing depend to a large extent upon the whiteness of the base paper.

2.2 In physical terms, a white surface is one which reflects strongly (usually more than 70%) throughout the visible spectrum. The higher and more uniform this spectral reflectance, the whiter the surface usually appears. From the point of view of geometry, a white surface is one that reflects diffusely in all directions. Mirrors, because they reflect only opposite the direction of illumination, are not called white, although a good mirror reflects strongly throughout the visible spectrum and would thus be judged white by its spectral reflectance curve.

3. Safety precautions

There are no specific safety precautions associated with this standard practice.

4. Procedure

4.1 In tests for preferences of white colors used in commerce, it is almost always shown that in the opponent-colors L,a,b -type systems, the b dimension measuring blueness-to-yellowness is the most critical of the three. In preference studies, minus b receives from three to four times the weight of any of the other scales. L is the next most important of the three dimensions, and a the least important in normal practice. It is probably true that any white would be undesirable as a white, if it attracted the attention of the layman by appearing bluish, pinkish, or greenish. In everyday practice, such whites are seldom encountered.

4.2 With many problems involving color technology of white materials, only one index of color is needed. The type of number required varies with the character of the problem. Thus, blue reflectance is used to measure progress in bleaching, but luminous reflectance is used to measure efficiency of white reflector surfaces. Table 1 lists four different single-scale measurements which have proved useful for problems involving the colors of white materials. These four single-number attributes of white surfaces are:

1. Whiteness index (WI)
2. Yellowness index (YI)
3. Paper brightness (blue reflectance)
4. Lightness (L) or luminous reflectance factor (Y or G)

4.3 Uses of each of these four indices in five industries are identified in Table 1. Equations for the four types of indices, the associated instruments and published test methods and their applications are listed in Table 2. Note that seven alternate equations for different whiteness indices and five alternate equations for different yellowness indices are provided.

4.3.1 *Whiteness indices* (WI) are widely measured to yield numbers correlating closely with consumers' preferences for white colors. An example of a simple whiteness index is that given by the equation $WI = 4B - 3G$. A colorimetrically similar equation yielding different numbers is $WI_{CDM} = L - 3b$. In both of the equations, yellowness is given three to four times the weight of grayness in the determination of visual departure from ideal white. These equations are presented for illustrative and historical reasons but are not recommended for current usage.

4.3.1.1 Note that two groups of scales are listed in Table 2 under whiteness indices. The first group comprises scales which favor neutral white. For these equations the whitest color possible is the color of the ideal white total reflecting standard. This ideal white is neither bluish nor yellowish and any departure from the chromaticity of this white standard results in values of whiteness index lower by one hundred than each of the three scales in this first group. The second group of scales comprises those which favor blue whites over neutral whites. With these scales as with the first group, the perfect white reflector is assigned the value 100, but with scales of the second group, it is quite possible to get bluish whites with whiteness indices well above 100. This is because bluishness counts more in the whiteness index equation than does high reflectance alone. Current experiments in visual grading of new white products tend to confirm the blue-white preferences expressed by the second group of whiteness indices.

4.3.1.2 In the Stensby whiteness index equation listed in Table 2, not only bluishness but pinkishness is favored. Here pink tints are rewarded and green tints are penalized.

4.3.1.3 The last equation provided for WI in Table 2 was adopted by the CIE in 1976 and by ASTM in 1996. It is designed to penalize both greenness and pinkness.

4.3.2 *Yellowness index* (YI) measurements are used primarily to study degradation of white color from raw materials, processing, or subsequent service exposure. The yellowing of paper due to light exposure should be measured by change in YI. The yellowness index equations all involve difference between Z (or B) and the other tristimulus values.

4.3.3 *Paper brightness (blue reflectance factor)* is, as was noted above, widely used to follow progress of bleaching and to evaluate a product for adequacy of bleaching or the addition of optical brighteners. The paper industry has for sixty years been using blue reflectance as its primary determinant of optical quality of paper pulp after bleaching. Since pulp is more likely to absorb blue light than the rest of the spectrum, brightness is a proper index of the optical quality of pulp. Brightness is an incomplete color index. For color of paper, one of the established tridimensional color scales should be used.

4.3.4 *Luminous reflectance factor* (Y) correlates with L and is used to evaluate the efficiency of surfaces as reflectors of light. As such, it is used for the specification of reflectors in floodlights. Luminous reflectance is also widely used to measure freedom of textile fabrics from dirt. This function is frequently used in the paper industry in the determination of opacity and scattering (see TAPPI T 425 "Opacity of Paper (15° Geometry, Illuminant A/2°, 89%