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As. 119.311

Señor
DIRECTOR DIVISIÓN DE NUEVAS CREACIONES
SUPERINTENDENCIA DE INDUSTRIA Y COMERCIO
E. S. D.

REF: Expediente No. **11 176311**– solicitud de patente de invención a favor de **VIDRIO PLANO DE MEXICO, S.A.** Título **UNA COMPOSICION DE VIDRIO SIN COLOR.**

RESPUESTA A EXAMEN DE FONDO

JUAN PABLO CADENA SARMIENTO, portador de la tarjeta profesional No. 57.492 del C.S.J., obrando como apoderado de la sociedad solicitante me permito dar respuesta al oficio número 10295 relacionado con la patentabilidad de la presente invención y notificado por fijación en lista el 18 de Junio de 2013.

Presentamos a consideración del señor examinador un nuevo pliego reivindicatorio, compuesto por (3) reivindicaciones, el cual remplaza el pliego anterior, en donde no se amplia en ningún momento la materia previamente divulgada y se encuentra enteramente sustentado en la descripción.

Con relación a las expresiones *de alrededor de* y *al menos* objetadas por el señor examinador por ser imprecisas, nos permitimos informar que dichas expresiones han sido eliminadas del nuevo pliego reivindicatorio.

Ahora bien, respecto a las expresiones *transmisión de luz visible, transmitancia de radiación ultravioleta, transmisión de radiación ultravioleta y longitud de onda dominante* objetadas por el señor examinador por ser resultados a alcanzar, nos permitimos señalar que dichas expresiones son características propias de la invención, ya que definen ***propiedades particulares de la composición reivindicada*** y en ningún momento hacen relación a resultados que se deseen obtener. En otras palabras, dichas expresiones son el resultado únicamente de la combinación específica de elementos reivindicados en las proporciones reivindicadas y no a cualquier otro tipo de vidrio. Por tal razón consideramos que las expresiones objetadas solo corresponden a la composición revindicada pero en ningún momento pretenden proteger "todas las alternativas presentes o futuras como lo sugiere el oficio técnico"

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Con relación a las expresiones *tinte de color y pureza* objetadas por ser resultados a alcanzar, nos permitimos señalar que las mismas han sido eliminadas del nuevo pliego reivindicatorio con el fin de superar dicha objeción.

Respecto a la objeción emitida por su despacho, relacionada con la reivindicación 4, nos permitimos informar que dicha reivindicación ha sido eliminada del nuevo pliego reivindicatorio.

Por otro lado, con relación a la objeción emitida por el señor examinador, según la cual los números de átomos de los compuestos están escritos de forma incorrecta, nos permitimos señalar que se han efectuado las correcciones necesarias al respecto. De igual forma, en el nuevo pliego reivindicatorio se han agregado las unidades correspondientes para las cantidades de óxido de cerio, oxido de titanio y de nitrato de sodio.

Nivel inventivo

Teniendo en cuenta que el señor Examinador afectó el nivel inventivo de la reivindicación 1, consideramos pertinente resaltar que aunque los documentos D1 y D2 revelan de manera aislada algunas características técnicas reveladas por la reivindicación 1, dichos documentos no sugieren de manera alguna la combinación de tales características, y por lo tanto para una persona versada en la materia no habría sido posible llegar a la composición acá reivindicada de manera obvia, partiendo de las enseñanzas de D1 y D2. Con el objetivo de sustentar esta afirmación procedemos a demostrar el nivel inventivo de la presente invención en vista de las referencias citadas por su Despacho.
En primer lugar, la referencia D1 describe una composición de vidrio que comprende 0.01-0.20% de hierro total (expresado como óxido de hierro), 0.1-15 ppm de óxido de cobalto, un valor redox de menos de 0.12, y 0.005-1% de óxido de cerio, además, dicha composición de vidrio tiene una transmisión visible de ≥ 88%, y se decolora con el fin de tener valores a* y b * entre -0.5 a 0.5. Adicionalmente, el documento D1 revela que la composición comprende de 0 a 10 ppm de óxido de cromo y, de 0 a 0.2% de oxido de Titanio, característica que se considera como <u>una alternativa</u> dentro de la composición del vidrio allí reivindicado.

Ahora bien, con respecto a la referencia D2, ésta hace relación a una composición de vidrio claro que comprende un vidrio base (por ejemplo una composición de vidrio sódico-sílico-cálcico) que a su vez comprende: SiO_2 en un 67-75%, Na_2O 10-20%, CaO 5-15%; y, adicionalmente una porción de colorante expresada en peso, que comprende: hierro total (expresado como Fe_2O_3) 0.54 a 0.30%, óxido de erbio 0.01 a 0.30%, óxido de cerio 0-0.30%, en donde el vidrio tiene una transmisión visible de al menos 80%, un valor de transmisión de color a* de 1.0 a 1.0 y un valor de transmisión de color b* de 1.0 a 1.5.

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Así mismo, dicha referencia D2 señala que una de las alternativas para obtener una transmisión visible de más o menos 85% es establecer un porcentaje de erbio determinado, por lo que es absolutamente claro que en dicha invención la presencia de este compuesto está directamente relacionada con las propiedades finales del vidrio allí revelado, compuesto que no es incluido dentro de la composición del vidrio aquí reivindicado. En este sentido, partiendo de los conocimientos de D2, una persona versada en la materia no habría recurrido a sus enseñanzas con tal de obtener una composición de vidrio con una transmisión de luz de al menos 87 % por que en D2 es esencial la utilización de erbio para lograr este resultado.

Así, lo mas obvio es que la persona versada en la materia no hubiera decidido eliminar el erbio allí descrito para desarrollar una composición como la acá reivindicada en donde precisamente el erbio se encuentra completamente ausente. Esta es una de las principales razones por la cual el documento D2 no puede ser un documento valido para afectar el nivel inventivo de la presente invención por la sencilla razón que sus enseñanzas van en contra del concepto inventivo de la presente invención.

No obstante lo anterior, es evidente que aunque las referencias citadas por el señor examinador incluyen características aisladas de la presente invención, la combinación de sus enseñanzas no llevarían de manera obvia a la combinación propuesta por la presente invención toda vez que para un versado en la materia esto representaría realizar diferentes estudios y análisis de variables para poder llegar a la composición tal como se reivindica, puesto que la modificación de cualquier compuesto o de sus proporciones se refleja en propiedades y características finales completamente diferentes como veremos mas adelante.

En este orden de ideas, consideramos muy relevante mencionar que las invenciones en cualquier campo técnico parten de elementos conocidos en donde precisamente lo que se busca es mejorar ciertas propiedades de compuestos, composiciones o dispositivos del arte previo o en el mejor de los casos proporcionar alternativas a las soluciones presentes en el estado de la técnica. Nunca una invención parte de la nada, sino que la misma parte de elementos ampliamente conocidos en el arte previo.

Esto es precisamente lo que se busca con la composición reivindicada, proporcionar una alternativa de composición de vidrio en donde se reivindica una combinación altamente específica de elementos –conocidos en el arte previo- en cantidades igualmente especificas con propiedades mejoradas para producir un vidrio con un alta transmisión de luz visible y baja transmisión de ultravioleta y de color neutro para su uso en la construcción, electrodomésticos, esmaltado e industria automotriz.

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En vista de lo anterior, notamos que el examinador simplifica al extremo el desarrollo de la composición reivindicada sin tener en cuenta que en su desarrollo se tuvieron en cuenta innumerables variables que podrían afectar las características finales del vidrio reivindicado ya sea por una selección inadecuada de elementos o por un error en las proporciones exactas de los elementos reivindicados.

En este punto es importante resaltar que en la invención se reivindican proporciones altamente específicas como **0.005 y 0.08 %** en peso de óxido férrico; entre **0.0002 y 0.0004 %** en peso de Se; entre **0.00003 y 0.0010%** en peso de Co_3O_4; entre **0.0001 y 0.005 %** en peso de CuO; entre **0 y 0.6 %** en peso de CeO_2; entre **0.02 y 1%** en peso de TiO_2, y entre **0 y 2 %** en peso de $NaNO_3$..

Es claro entonces que el desarrollo de la composición de vidrio resultante es el resultado de un estudio cuidadoso de los elementos de la invención y su interacción físico-química, así como de las proporciones de cada uno de estos en la composición. Es importante tener en cuenta además, que un cambio mínimo en la composición ya sea en los elementos reivindicados o en sus proporciones podría repercutir en una composición totalmente diferente que no podría solucionar de igual manera el problema técnico que si soluciona la composición reivindicada.

De esta manera, respecto al análisis llevado a cabo por el señor examinador, en el que menciona que no se observa ningún efecto técnico porque la solución de la presente invención posee las mismas características de color y transmisión de luz presentes en el documento D1, nos permitimos disentir enormemente, ya que cualquier variación en los rangos de color L*, a* y b* en base a los componentes seleccionados **puede variar significativamente las propiedades del vidrio resultante.** Al respecto, nos permitimos referenciar el documento *A Guide to Understanding Color Communication,* adjunto como soporte del presente memorial, en el cual se menciona específicamente que la variación de dichos valores de L* (que denota luminosidad), a* (variación entre rojo/verde) y b* (variación entre amarillo/azul) otorga características particulares, relacionadas con la percepción de los colores que se obtiene, así pues, cualquier modificación en el rango de dichos valores se traduce en un vidrio con propiedades y características cromáticas totalmente diferentes, las cuales a su vez están relacionadas con propiedades de transmisión de luz particulares.

Por lo tanto, insistimos nuevamente en que las invenciones buscan diferentes alternativas o combinaciones de componentes que otorguen características particulares que lleguen a una misma finalidad sin que ello signifique que la presencia de un efecto inesperado sea la única forma posible para reconocer nivel inventivo a una invención.

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Adicionalmente, no estamos de acuerdo con la posición de su despacho en el sentido de que al presentar la presente invención las mismas características de color y transmisión de luz de D1 la misma no tiene nivel inventivo ya que de aceptarse este argumento, entonces ninguna composición de vidrio novedosa e inventiva con dicha propiedad seria patentable. Lo que se despacho debe demostrar es que la invención en vista de sus características técnicas esenciales era o no obvia en vista del arte previo. Haciendo un paralelo con la objeción del examinador seria equivalente a decir que un compuesto diabético de tipo heterocíclico no es inventivo porque ya se conocen compuestos con actividad antidiabética.

Ahora bien, es importante señalar que con la composición de la presente invención y sus proporciones específicas se obtienen mejoras considerables en las propiedades físicas del vidrio resultante, específicamente en una alta transmisión de la luz visible, baja transmisión de ultravioleta, transmisión de energía solar, longitud de onda dominante y pureza de excitación, para uso en la industria de la construcción, electrodomésticos esmaltado e industria automotriz, en donde dichas propiedades son estándares requeridos por la industria automotriz o de la construcción, razón por la cual, las diversas invenciones buscan ***diferentes alternativas*** o combinación de componentes para llegar a la misma finalidad; siendo la presente invención, <u>una de esas alternativas</u> que permite obtener un vidrio claro con propiedades físicas diferentes para uso en la industria automotriz. De esta forma el hecho de que D1 presente las mimas características de color y transmisión de luz no puede ser un argumento valido que desvirtúe la patentabilidad de la presente invención toda vez que lo que se debe demostrar es que el estado de la técnica en su conjunto haya sugerido de forma abierta la forma de llegar a la presente invención de manera obvia.

En cuanto a las ventajas de la presente invención podemos decir que la misma mejora la composición del vidrio con ventajas a menor costo y sin afectar las condiciones de operación del horno, debido a la utilización de materiales convencionales y que no se requiere la especificación de un vidrio para celdas solares, características que evidentemente son logradas con la composición aquí reivindicada.

Así las cosas, consideramos que a partir de las enseñanzas reveladas en el documento D2 donde se mencionan diferentes compuestos, en diferentes proporciones no era obvio para una persona versada en la materia tomar específicamente dentro de los compuestos allí mencionados el nitrato de sodio y adicionarlo a las composiciones reveladas en el documento D1 sin haber realizado extensos estudios y análisis para la obtención de una composición de vidrio claro.

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Para sustentar lo anterior, resulta de la mayor relevancia argumentar que la combinación de dos o más compuestos tiene un efecto aditivo en la absorción, y por tanto en las propiedades finales del producto. Adicionalmente, las cantidades, proporciones y el estado de oxidación-reducción de cada uno de los colorantes que se empleen están directamente relacionados con la alternación de algunos parámetros fundamentales en las propiedades del producto, como lo son sus transmisiones en las tres zonas del espectro electromagnético en el que la radiación solar reside, es decir, ultravioleta, visible e infrarrojo cercano, así como, el color de la transmisión del vidrio, y por lo tanto, cualquier alteración de dichas variables o combinación de los componentes en diferentes proporciones conducirá a la **obtención de un vidrio totalmente inesperado.**

En otras palabras, el color y las propiedades de cada vidrio en particular dependen de muchos factores, como por ejemplo:

- Los componentes específicos presentes en el vidrio;

- El estado de valencia de cada uno de los componentes;

- Las cantidades de los componentes específicos;

- Las cantidades específicas de los otros componentes;

- La reacción entre los componentes.

Es por esta razón que el documento D1 no es un documento que haya guiado de manera obvia al versado en la materia a la presente invención ya que el versado en la materia se veía enfrentado a un gran número de posibilidades de compuestos y frente a los cuales dicho versado en la materia tendría que controlar todos y cada uno de los parámetros arriba mencionados con tal de llegar a la presente invención. De igual manera, D2 no contiene ninguna sugerencia que le hubiera permitido llegar de **manera obvia** a la presente invención.

Por el contrario, el versado en la materia al tener que controlar todas y cada una de las variables mencionadas tendría que emplear actividad inventiva y más aun teniendo en cuenta que el estado de la técnica no sugiere en ningún momento la forma de controlar dichas variables con el fin de obtener la composición reivindicada.

Así pues, la composición acá reivindicada emplea una serie de **componentes, y cantidades** altamente específicas que no se enseñan ni se sugieren en ninguno de los documentos citados como estado de la técnica. Adicionalmente el control de las variables previamente mencionadas no pueden ser determinadas por una simple observación o análisis de los vidrios existentes, o por simples ensayos experimentales

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ya que la alteración de una o más de las mencionadas variables **conduce a un vidrio completamente inesperado**, cada uno con sus propias propiedades específicas.

Por tanto, la composición de vidrio acá reivindicada es el resultado de un arduo esfuerzo en investigación y desarrollo de los inventores de la presente invención en donde se evaluaron cuidosamente factores como los anteriormente mencionados, **componentes específicos, estado de valencia de los mismos, equilibro y balance de los compuestos incluidos, cantidades y reacción entre dichos componentes**, y por lo tanto, evidentemente es imposible obtener la presente invención de manera obvia a partir del estado de la técnica ya que dicho estado de la técnica en ningún momento sugiere las modificaciones que permitan llegar a la invención reivindicada.

Además, reiteramos que la modificación de la composición y de sus proporciones no es una operación rutinaria toda vez que influye de manera considerable sobre las propiedades finales del vidrio y consecuentemente <u>requiere un esfuerzo inventivo</u> significativo por parte del inventor.

En este orden de ideas, la conclusión de su despacho según la cual: *La persona versada en la materia incluiría el nitrato de sodio de D2 en la composición de D1 esperando con certeza lograr el producto de la reivindicación 1,* solo es posible mediante un análisis en retrospectiva partiendo de la solución propuesta por la presente invención (componentes y proporciones) e identificando cada una de dichas características en los documentos D1 y D2 de manera independiente. Sin embargo, lo cierto es que el estado de la técnica en su conjunto en ningún momento sugería la manera de llegar de forma obvia a la presente invención en donde se reivindican unos componentes y proporciones altamente específicos.

Por otra parte, no podemos estar mas en desacuerdo con la argumentación de su despacho según la cual el versado en la materia lograría <u>*con certeza*</u> el producto reivindicado ya que quedo ampliamente demostrado a lo largo del presente memorial que en la obtención de una composición de vidrio se tienen que controlar innumerables variables que pueden afectar considerablemente todas y cada una de las propiedades del producto final y no es el simple resultado de experimentación de rutina o la escogencia al azar de una serie de elementos en proporciones indefinidas.
Como evidencia adicional del nivel inventivo de la invención, adjuntados copia de la respectiva Patente de estados Unidos en donde las reivindicaciones allí concedidas presentan un alcance muy similar al acá reivindicado.

Así pues, y teniendo en cuenta lo anterior, la reivindicación 1 y sus dependientes cumplen con el requisito de nivel inventivo a la luz de los documentos del estado del arte.

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Por todo lo anterior, solicitamos el retiro de las objeciones de la presente solicitud y la concesión del privilegio solicitado, ya que en opinión del solicitante cumple con todos los requisitos establecidos en la Decisión 486.

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REIVINDICACIONES

1.- Una composición de vidrio sin color teniendo una composición de vidrio base, la cual comprende: entre 0.005 y 0.08 % en peso de óxido férrico; entre 0.0002 y 0.0004 % en peso de Se; entre 0.00003 y 0.0010% en peso de Co_3O_4; entre 0.0001 y 0.005 % en peso de CuO; entre 0 y 0.6 % en peso de CeO_2; entre 0.02 y 1% en peso de TiO_2, y entre 0 y 2 % en peso de $NaNO_3$; el vidrio teniendo una transmisión de luz visible de al menos 87%; una trasmitancia de radiación ultravioleta de menos de 85% y una transmisión solar directa de no más de 90%; y una longitud de onda dominante de al menos 491 nm.

2. La composición de vidrio sin color tal como se reclama en la reivindicación 1, donde dicho vidrio es producido con un espesor de alrededor de 4 milímetros.

3. La composición de vidrio sin color tal como se reclama en la reivindicación 1, en donde dicho vidrio teniendo valores L* a* b* como se define en el Iluminante CIE D65 y 10° observador de referencia, en los rangos a* (verde-rojo) de 1 a -1,5; b* (azul-amarillo) 1,0 a -1,0 y con un valor L* mayor de 95.

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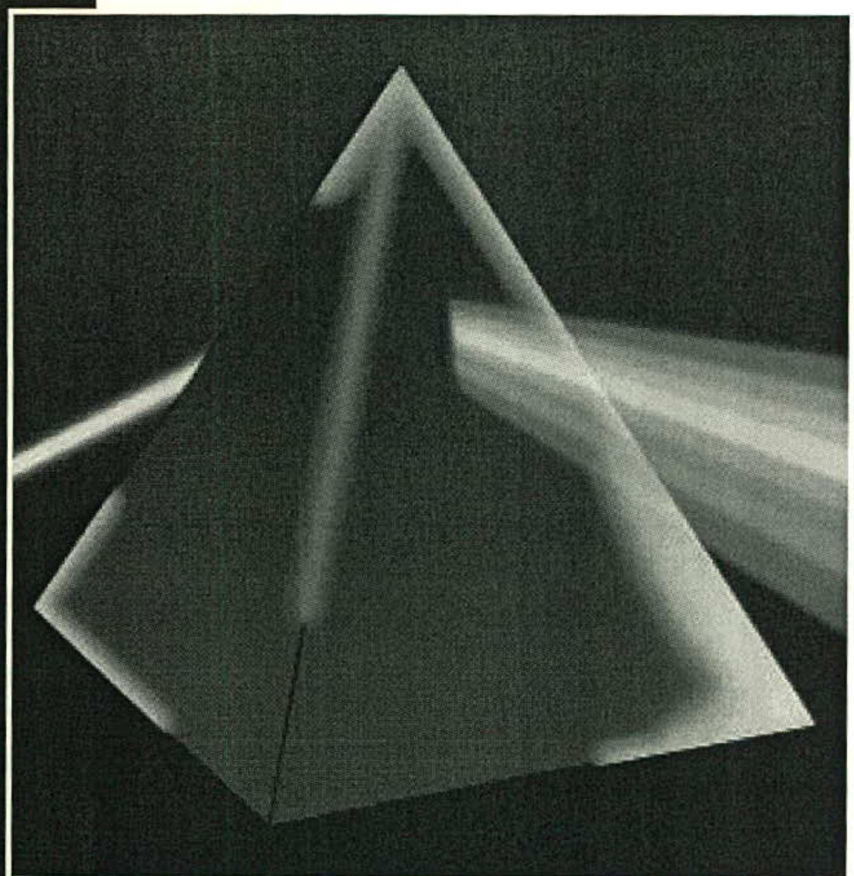
A Guide to
Understanding Color Communication



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Sincerely,

Rich

Rich Cook
President

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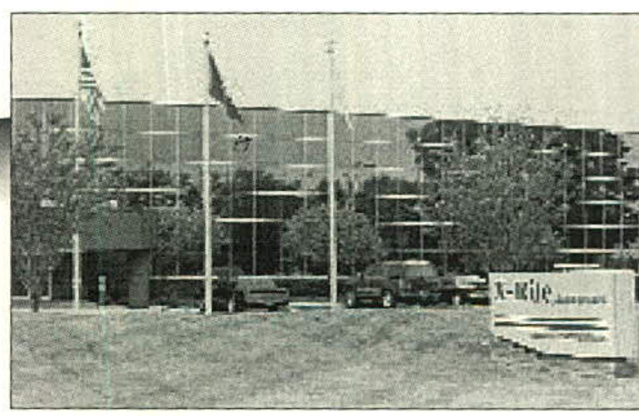

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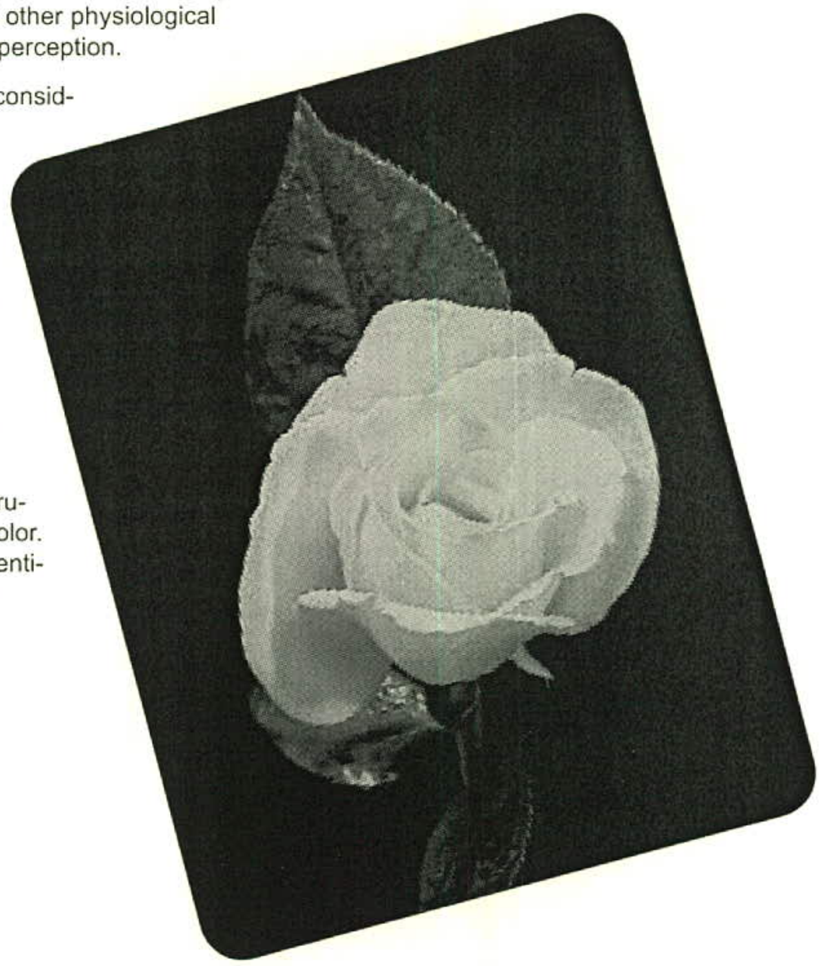
Communicating Color

How would you describe the color of this rose? Would you say it's yellow, sort of lemony yellow or maybe a bright canary yellow?

Your perception and interpretation of color are highly subjective. Eye fatigue, age and other physiological factors can influence your color perception.



But even without such physical considerations, each observer interprets color based on personal references. Each person also verbally defines an object's color differently.

As a result, objectively communicating a particular color to someone without some type of standard is difficult. There also must be a way to compare one color to the next with accuracy.

The solution is a measuring instrument that explicitly identifies a color. That is, an instrument that differentiates a color from all others and assigns it a numeric value.

Ways to Measure Color

Today, the most commonly used instruments for measuring color are spectrophotometers.

Spectro technology measures reflected or transmitted light at many points on the visual spectrum, which results in a curve. Since each color sample's curve is as unique as a signature or fingerprint, the curve is an excellent tool for identifying, specifying and matching color.

A portable sphere spectrophotometer measures the color of textile samples and other materials where the product's appearance is critical for buyer acceptability.

A spectrophotometer is essential in the color formulation of various products, including plastics, paints, inks, textiles and metals.

```
DENSITY (STATUS T)
V  1.84
C  1.39
M  1.55
Y  1.11

DOT AREA, 50% TINT
V  79%
C  77%
M  77%
```

A spectrodensitometer measures the color bar on a press sheet to monitor color reproduction. A typical printout (left) shows the visual, cyan, magenta and yellow values for density, dot area and other characteristics.

Attributes of Color

Each color has its own distinct appearance, based on three elements: hue, chroma and value (lightness). By describing a color using these three attributes, you can accurately identify a particular color and distinguish it from any other.

Hue

When asked to identify the color of an object, you'll most likely speak first of its hue. Quite simply, hue is how we perceive an object's color — red, orange, green, blue, etc.

The color wheel in Figure 1 shows the continuum of color from one hue to the next. As the wheel illustrates, if you were to mix blue and green paints, you would get blue-green. Add yellow to green for yellow-green, and so on.

Chroma

Chroma describes the vividness or dullness of a color — in other words, how close the color is to either gray or the pure hue. For example, think of the appearance of a tomato and a radish. The red of the tomato is vivid, while the radish appears duller.

Figure 2 shows how chroma changes as we move from center to the perimeter. Colors in the center are gray (dull) and become more saturated (vivid) as they move toward the perimeter. Chroma also is known as saturation.

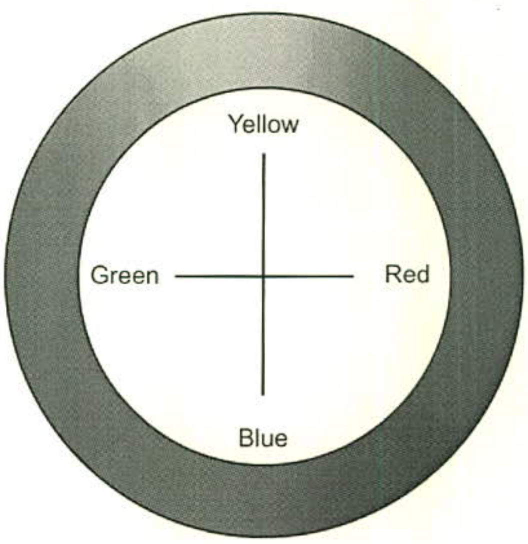


Figure 1: Hue

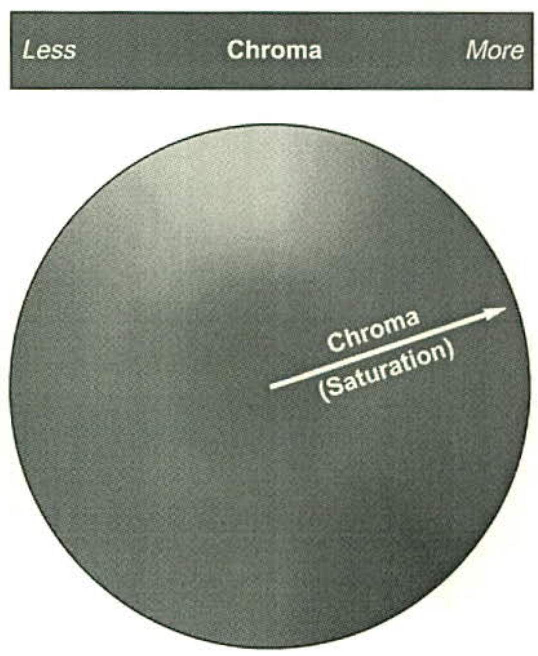


Figure 2: Chromaticity

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Lightness

The luminous intensity of a color — i.e., its degree of lightness — is called its value. Colors can be classified as light or dark when comparing their value.

For example, when a tomato and a radish are placed side by side, the red of the tomato appears to be much lighter. In contrast, the radish has a darker red value. In Figure 3, the value, or lightness, characteristic is represented on the vertical axis.

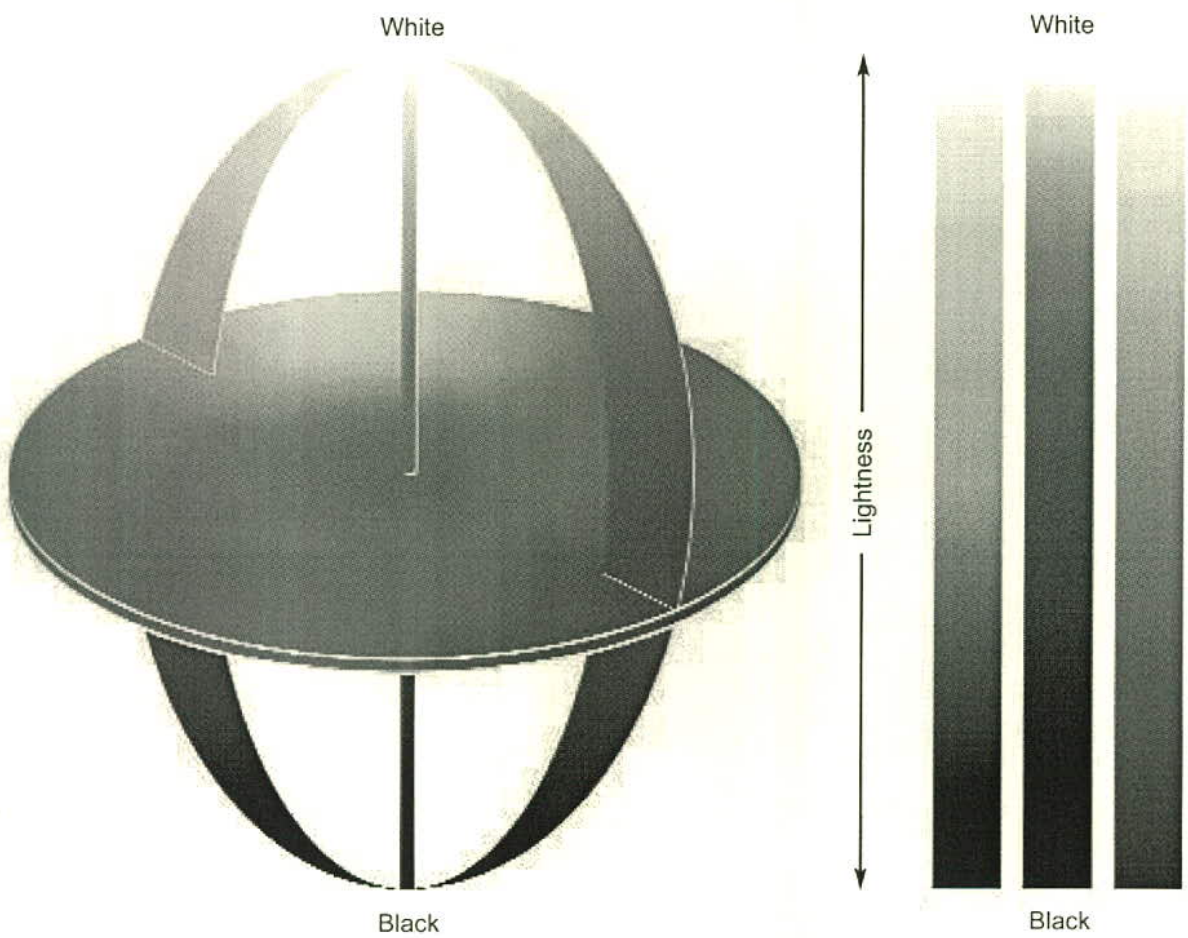

Figure 3: Three-dimensional color system depicting lightness

Scales for Measuring Color

The Munsell Scale

In 1905, artist Albert H. Munsell originated a color ordering system — or color scale — which is still used today. The Munsell System of Color Notation is significant from a historical perspective because it's based on human perception. Moreover, it was devised before instrumentation was available for measuring and specifying color. The Munsell System assigns numerical values to the three properties of color: hue, value and chroma. Adjacent color samples represent equal intervals of visual perception.

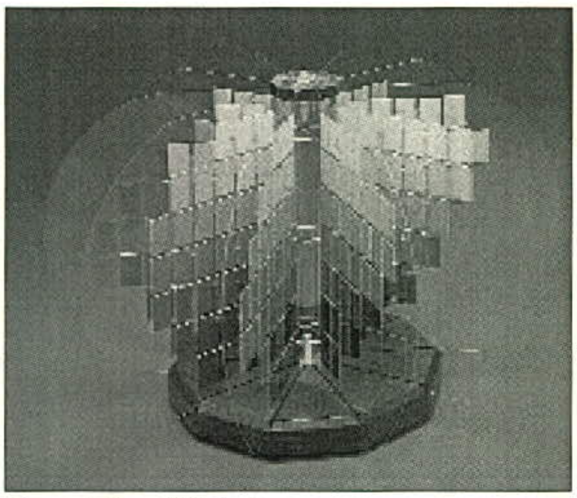

Figure 4: Munsell Color Tree

The model in Figure 4 depicts the Munsell Color Tree, which provides physical samples for judging visual color. Today's color systems rely on instruments that utilize mathematics to help us judge color.

Three things are necessary to see color:

- A light source (illuminant)
- An object (sample)
- An observer/processor

We as humans see color because our eyes process the interaction of light hitting an object. What if we replace our eyes with an instrument — can it see and record the same color differences that our eyes detect?

CIE Color Systems

The CIE, or Commission Internationale de l'Eclairage (translated as the International Commission on Illumination), is the body responsible for international recommendations for photometry and colorimetry. In 1931 the CIE standardized color order systems by specifying the light source (or illuminants), the observer and the methodology used to derive values for describing color.

The CIE Color Systems utilize three coordinates to locate a color in a color space. These color spaces include:

- CIE XYZ
- CIE L*a*b*
- CIE L*C*h°

To obtain these values, we must understand how they are calculated.

As stated earlier, our eyes need three things to see color: a light source, an object and an observer/processor. The same must be true for instruments to see color. Color measurement instruments receive color the same way our eyes do — by gathering and filtering the wavelengths of light reflected from an object. The instrument perceives the reflected light wavelengths as numeric values. These values are recorded as points across the visible spectrum and are called spectral data. Spectral data is represented as a spectral curve. This curve is the color's fingerprint (Figure 5).

Once we obtain a color's reflectance curve, we can apply mathematics to convert the color into a color space.

To do this, we take the reflectance curve and multiply the data by a CIE standard illuminant. The illuminant is a graphical representation of the light source under which the samples are viewed. Each light source has a power distribution that affects how we see color. Examples of different illuminants are A — incandescent, D65 — daylight (Figure 6) and F2 — fluorescent.

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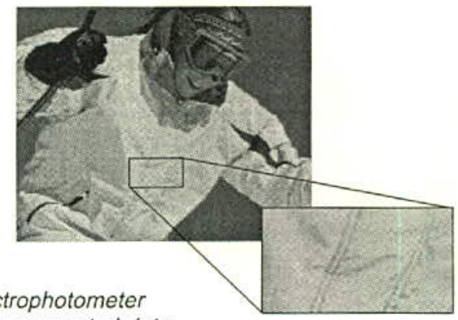


A spectrophotometer measures spectral data – the amount of light energy reflected from an object at several intervals along the visible spectrum. The spectral data is shown as a spectral curve.

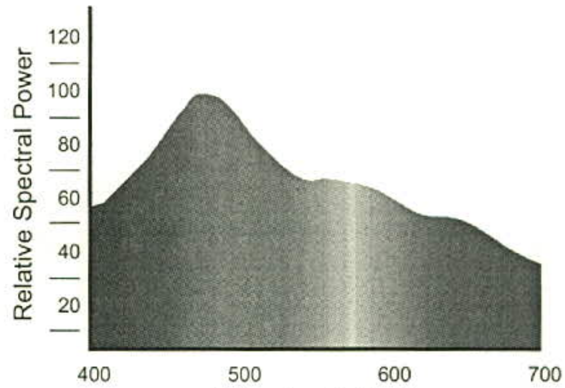


Figure 6: Daylight (Standard Illuminant D65/10°)

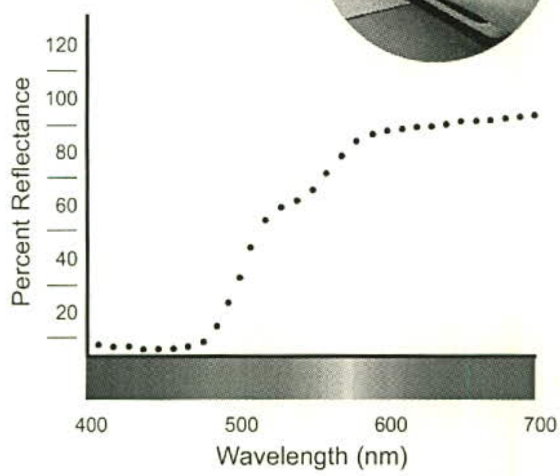


Figure 5: Spectral curve from a measured sample

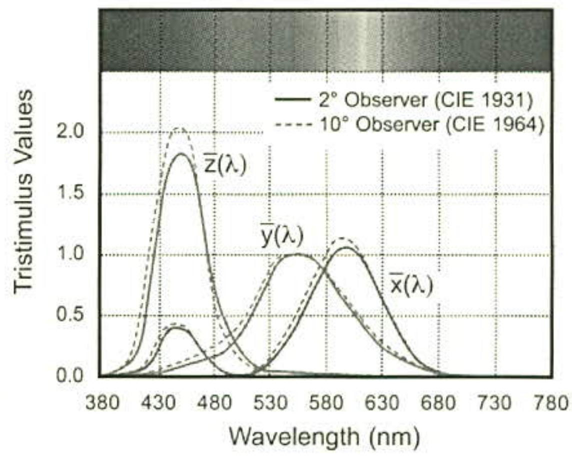


Figure 7: CIE 2° and 10° Standard Observers

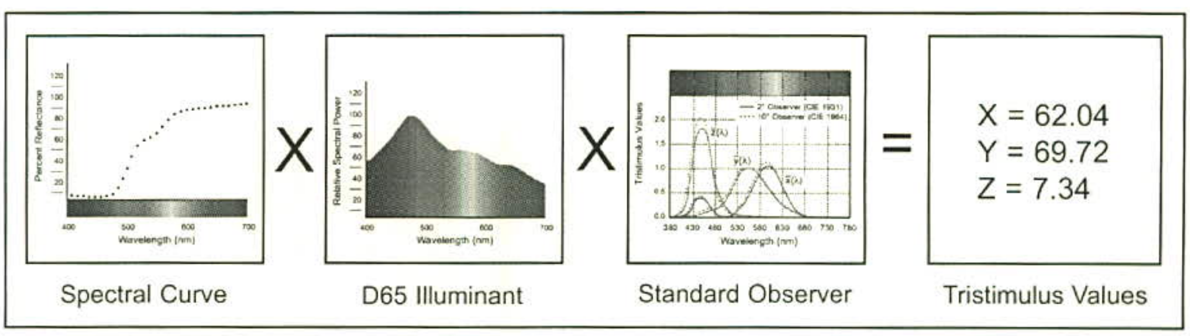


Figure 8: Tristimulus values

We multiply the result of this calculation by the CIE standard observer. The CIE commissioned work in 1931 and 1964 to derive the concept of a standard observer, which is based on the average human response to wavelengths of light (Figure 7).

In short, the standard observer represents how an average person sees color across the visible spectrum. Once these values are calculated, we convert the data into the tristimulus values of XYZ (Figure 8). These values can now identify a color numerically.

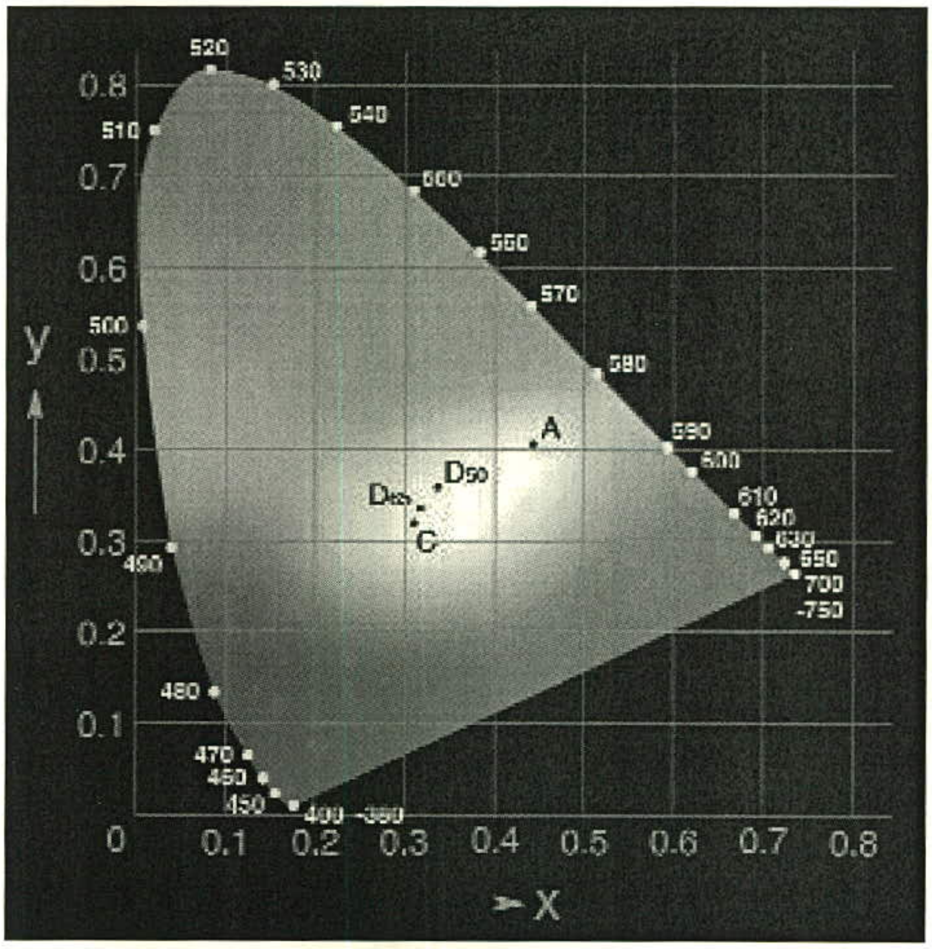


Figure 9: CIE 1931 (x, y) chromaticity diagram

Chromaticity Values

Tristimulus values, unfortunately, have limited use as color specifications because they correlate poorly with visual attributes. While Y relates to value (lightness), X and Z do not correlate to hue and chroma.

As a result, when the 1931 CIE standard observer was established, the commission recommended using the chromaticity coordinates xyz. These coordinates are used to form the chromaticity diagram in Figure 9. The notation Yxy specifies colors by identifying value (Y) and the color as viewed in the chromaticity diagram (x,y).

As Figure 10 shows, hue is represented at all points around the perimeter of the chromaticity diagram. Chroma, or saturation, is represented by a movement from the central white (neutral) area out toward the diagram's perimeter, where 100% saturation equals pure hue.

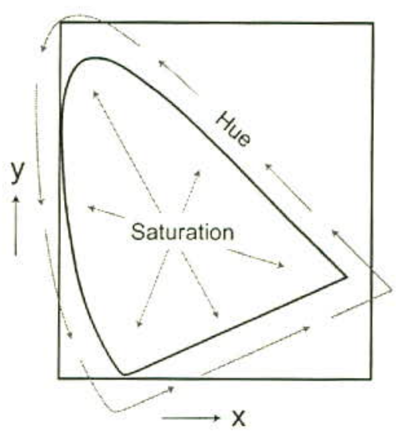


Figure 10: Chromaticity diagram

Expressing Colors Numerically

To overcome the limitations of chromaticity diagrams like Yxy, the CIE recommended two alternate, uniform color scales: CIE 1976 (L*a*b*) or CIELAB, and CIELCH (L*C*h°).

These color scales are based on the opponent-colors theory of color vision, which says that two colors cannot be both green and red at the same time, nor blue and yellow at the same time. As a result, single values can be used to describe the red/green and the yellow/blue attributes.

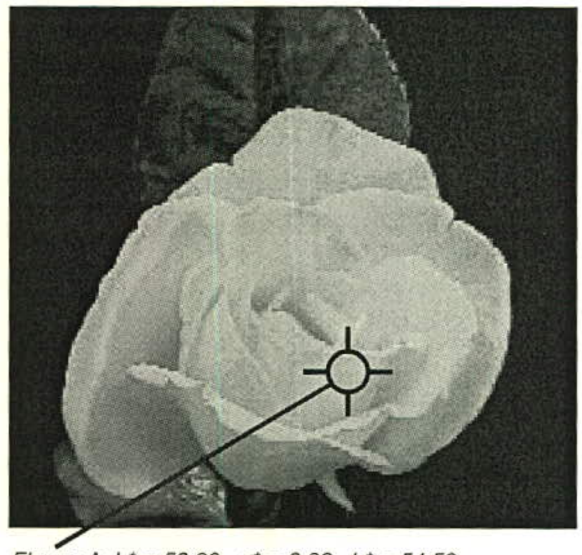
CIELAB (L*a*b*)

When a color is expressed in CIELAB, L* defines lightness, a* denotes the red/green value and b* the yellow/blue value.

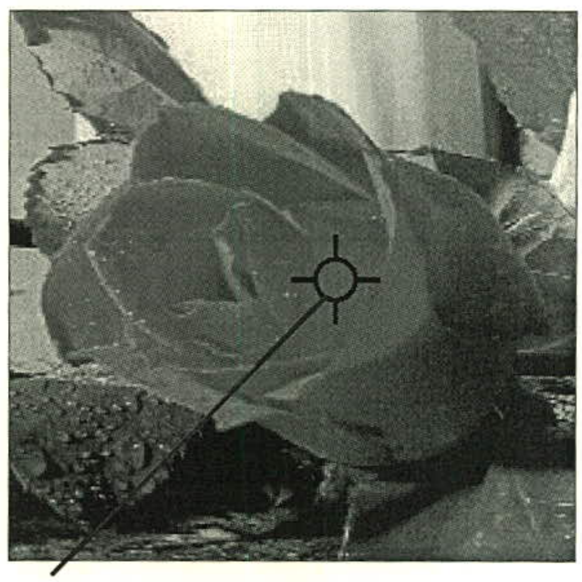
Figures 11 and 12 show the color-plotting diagrams for L*a*b*. The a* axis runs from left to right. A color measurement movement in the +a direction depicts a shift toward red. Along the b* axis, +b movement represents a shift toward yellow. The center L* axis shows L = 0 (black or total absorption) at the bottom. At the center of this plane is neutral or gray.

To demonstrate how the L*a*b* values represent the specific colors of Flowers A and B, we've plotted their values on the CIELAB Color Chart in Figure 11.

The a* and b* values for Flowers A and B intersect at color spaces identified respectively as points A and B (see Figure 11). These points specify each flower's hue (color) and chroma (vividness/dullness). When their L* values (degree of lightness) are added in Figure 12, the final color of each flower is obtained.



Flower A: L = 52.99   a* = 8.82   b* = 54.53*



Flower B: L = 29.00   a* = 52.48   b* = 22.23*

CIELCH (L*C*h°)

While CIELAB uses Cartesian coordinates to calculate a color in a color space, CIELCH uses polar coordinates. This color expression can be derived from CIELAB. The L* defines lightness, C* specifies chroma and h° denotes hue angle, an angular measurement.

The L*C*h° expression offers an advantage over CIELAB in that it's very easy to relate to the earlier systems based on physical samples, like the Munsell Color Scale.

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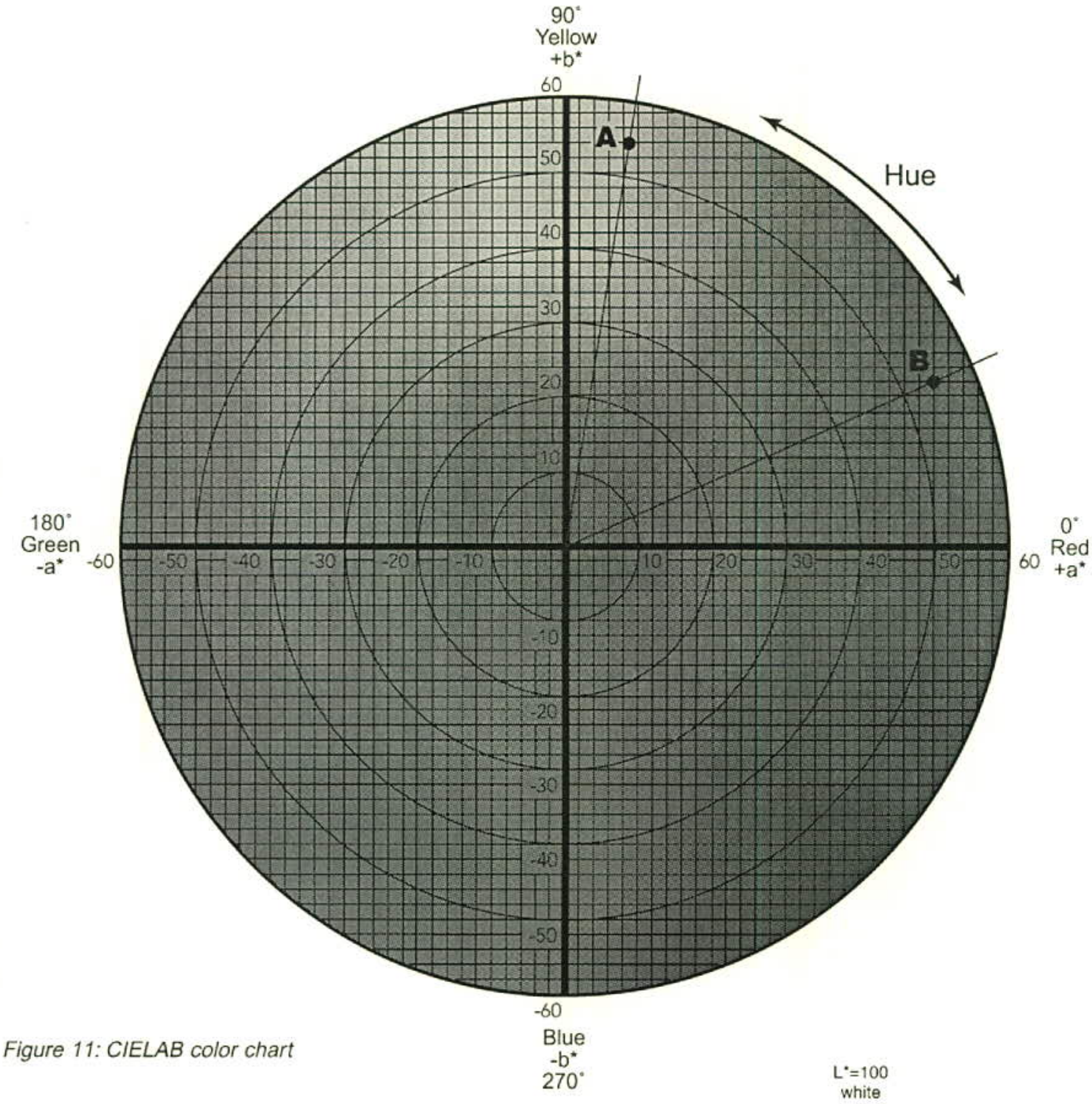


Figure 11: CIELAB color chart

$L^* = 116\ (Y/Y_n)^{1/3} - 16$

$a^* = 500\ [(X/X_n)^{1/3} - (Y/Y_n)^{1/3}]$

$b^* = 200\ [(Y/Y_n)^{1/3} - (Z/Z_n)^{1/3}]$

$L^* = 116\ (Y/Y_n)^{1/3} - 16$

$C^* = (a^2 + b^2)^{1/2}$

$h° = \arctan\ (b^*/a^*)$

X_n, Y_n, Z_n, are values for a reference white for the illumination/observer used.

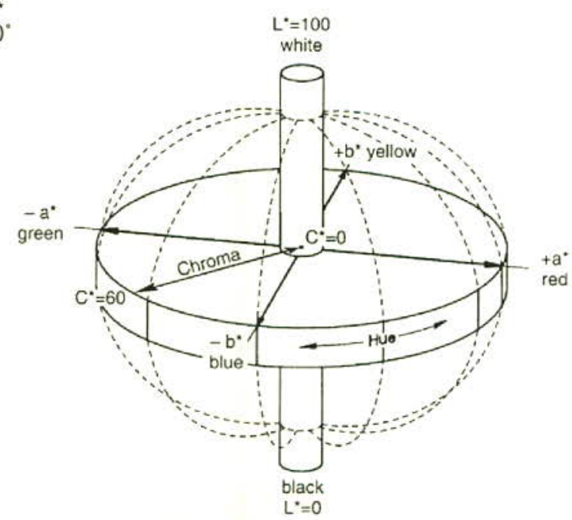


Figure 12: The L value is represented on the center axis. The a* and b* axes appear on the horizontal plane.*

Color Differences, Notation and Tolerancing

Delta CIELAB and CIELCH

Assessment of color is more than a numeric expression. Usually it's an assessment of the color difference (delta) from a known standard. CIELAB and CIELCH are used to compare the colors of two objects. The expressions for these color differences are ΔL^* Δa^* Δb^* or DL* Da* Db*, and ΔL^* ΔC^* ΔH^* or DL* DC* DH*

(Δ or D symbolizes "delta," which indicates difference).

Given ΔL^* Δa^* Δb^*, the total difference or distance on the CIELAB diagram can be stated as a single value, known as ΔE^*.

$$\Delta E^*_{ab} = [(\Delta L^2) + (\Delta a^2) + (\Delta b^2)]^{1/2}$$

Let's compare the color of Flower A to Flower C, pictured below. Separately, each would be classified as a yellow rose. But what is their relationship when set side by side? How do the colors differ?

Using the equation for ΔL^* Δa^* Δb^*, the color difference between Flower A and Flower C can be expressed as:

$$\Delta L^* = +11.10 \quad \Delta a^* = -6.10 \quad \Delta b^* = -5.25$$

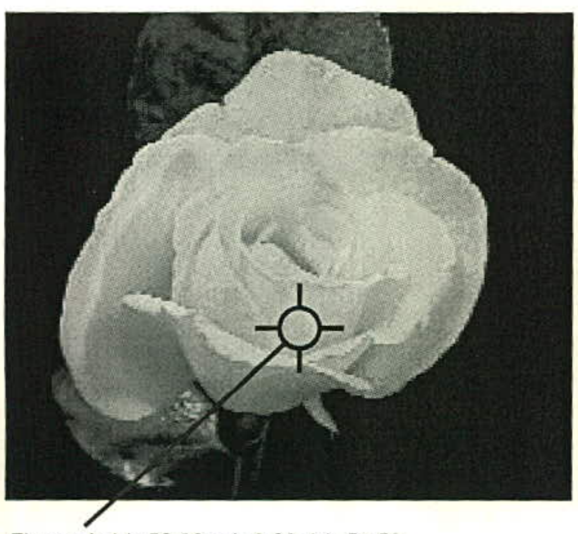
The total color difference can be expressed as $\Delta E^*=13.71$

The values for Flowers A and C are shown at the bottom of this page. On the a* axis, a reading of –6.10 indicates greener or less red. On the b* axis, a reading of –5.25 indicates bluer or less yellow. On the L* plane, the measurement difference of +11.10 shows that Flower C is lighter than Flower A.

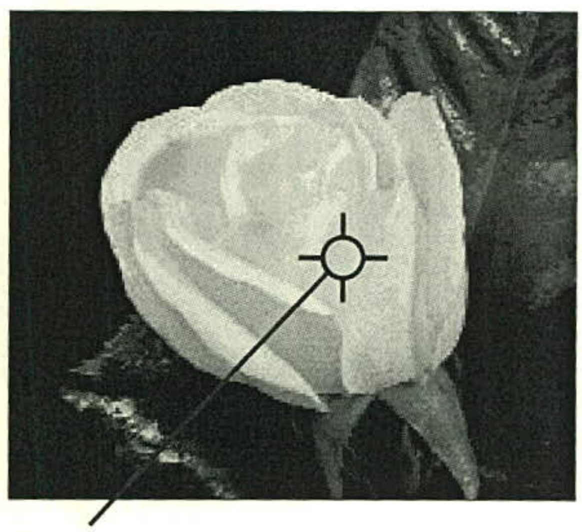
If the same two flowers were compared using CIELCH, the color differences would be expressed as:

$$\Delta L^* = +11.10 \quad \Delta C^* = -5.88 \quad \Delta H^* = 5.49$$

Referring again to the flowers shown below, the ΔC^* value of –5.88 indicates that Flower C is less chromatic, or less saturated. The ΔH^* value of 5.49 indicates that Flower C is greener in hue than Flower A. The L* and ΔL^* values are identical for CIELCH and CIELAB.



Flower A: $L^*=52.99$ $a^*=8.82$ $b^*=54.53$



Flower C: $L^*=64.09$ $a^*=2.72$ $b^*=49.28$

Color difference of Flower C to A

$$\Delta L^* = +11.10,\ \Delta a^* = -6.10,\ \Delta b^* = -5.25$$
$$\Delta E^*_{ab} = [(+11.1)^2 + (-6.1)^2 + (-5.25)^2]^{1/2}$$
$$\Delta E^*_{ab} = 13.71$$

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CIE Color Space Notation

ΔL* = difference in lightness/darkness value
+ = *lighter* — = *darker*

Δa* = difference on red/green axis
+ = *redder* — = *greener*

Δb* = difference on yellow/blue axis
+ = *yellower* — = *bluer*

ΔC* = difference in chroma
+ = *brighter* — = *duller*

ΔH* = difference in hue

ΔE* = total color difference value

Refer to Figure 11 on page 12.

Visual Color and Tolerancing

Poor color memory, eye fatigue, color blindness and viewing conditions can all affect the human eye's ability to distinguish color differences. In addition to those limitations, the eye does not detect differences in hue (red, yellow, green, blue, etc.), chroma (saturation) or lightness equally. In fact, the average observer will see hue differences first, chroma differences second and lightness differences last. Visual acceptability is best represented by an ellipsoid (Figure 13).

As a result, our tolerance for an acceptable color match consists of a three-dimensional boundary with varying limits for lightness, hue and chroma, and must agree with visual assessment. CIELAB and CIELCH can be used to create those boundaries. Additional tolerancing formulas, known as CMC and CIE94, produce ellipsoidal tolerances.

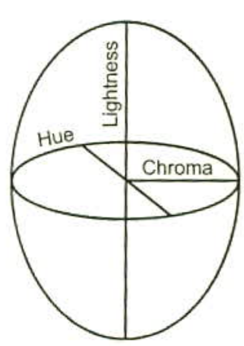

Figure 13: Tolerance ellipsoid

CIELAB Tolerancing

When tolerancing with CIELAB, you must choose a difference limit for ΔL* (lightness), Δa* (red/green), and Δb* (yellow/blue). These limits create a rectangular tolerance box around the standard (Figure 14).

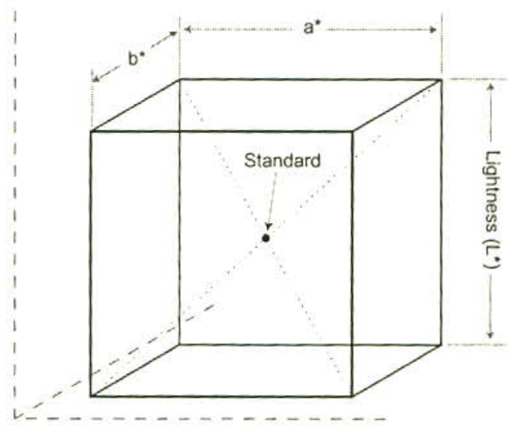

Figure 14: CIELAB tolerance box

When comparing this tolerance box with the visually accepted ellipsoid, some problems emerge. A box-shaped tolerance around the ellipsoid can give good numbers for unacceptable color. If the tolerance box is made small enough to fit within the ellipsoid, it is possible to get bad numbers for visually acceptable color (Figure 15).

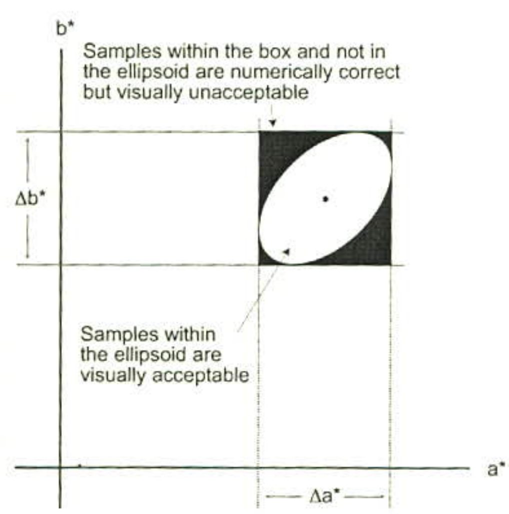

Figure 15: Numerically correct vs. visually acceptable

CIELCH Tolerancing

CIELCH users must choose a difference limit for ΔL* (lightness), ΔC* (chroma) and ΔH* (hue). This creates a wedge-shaped box around the standard. Since CIELCH is a polar-coordinate system, the tolerance box can be rotated in orientation to the hue angle (Figure 16).

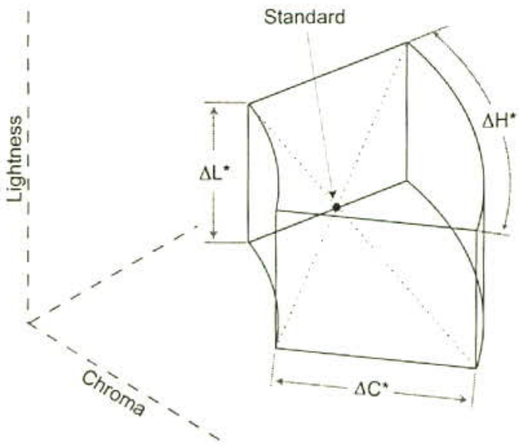

Figure 16: CIELCH tolerance wedge

When this tolerance is compared with the ellipsoid, we can see that it more closely matches human perception. This reduces the amount of disagreement between the observer and the instrumental values (Figure 17).

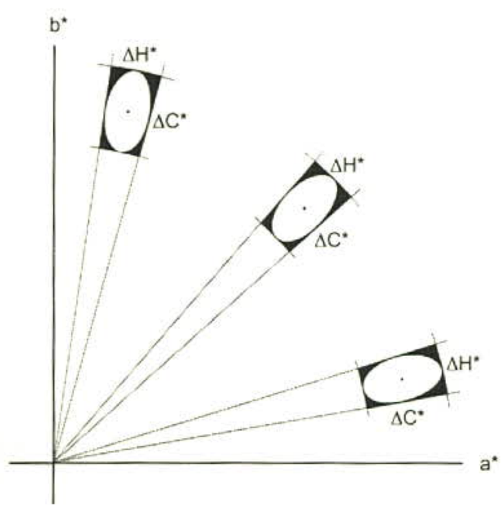

Figure 17: CIELCH tolerance ellipsoids

CMC Tolerancing

CMC is not a color space but rather a tolerancing system. CMC tolerancing is based on CIELCH and provides better agreement between visual assessment and measured color difference. CMC tolerancing was developed by the Colour Measurement Committee of the Society of Dyers and Colourists in Great Britain and became public domain in 1988.

The CMC calculation mathematically defines an ellipsoid around the standard color with semi-axis corresponding to hue, chroma and lightness. The ellipsoid represents the volume of acceptable color and automatically varies in size and shape depending on the position of the color in color space.

Figure 18 shows the variation of the ellipsoids throughout color space. The ellipsoids in the orange area of color space are longer and narrower than the broader and rounder ones in the green area. The size and shape of the ellipsoids also change as the color varies in chroma and/or lightness.

The CMC equation allows you to vary the overall size of the ellipsoid to better match what is visually acceptable. By varying the commercial factor (cf), the ellipsoid can be made as large or small as necessary to match visual assessment. The cf value is the tolerance, which means that if cf=1.0, then ΔE CMC less than 1.0 would pass, but more than 1.0 would fail (Figure 19).

Since the eye will generally accept larger differences in lightness (l) than in chroma (c), a default ratio for (l:c) is 2:1. A 2:1 ratio will allow twice as much difference in lightness as in chroma. The CMC equation allows this ratio to be adjusted to achieve better agreement with visual assessment (Figure 20).

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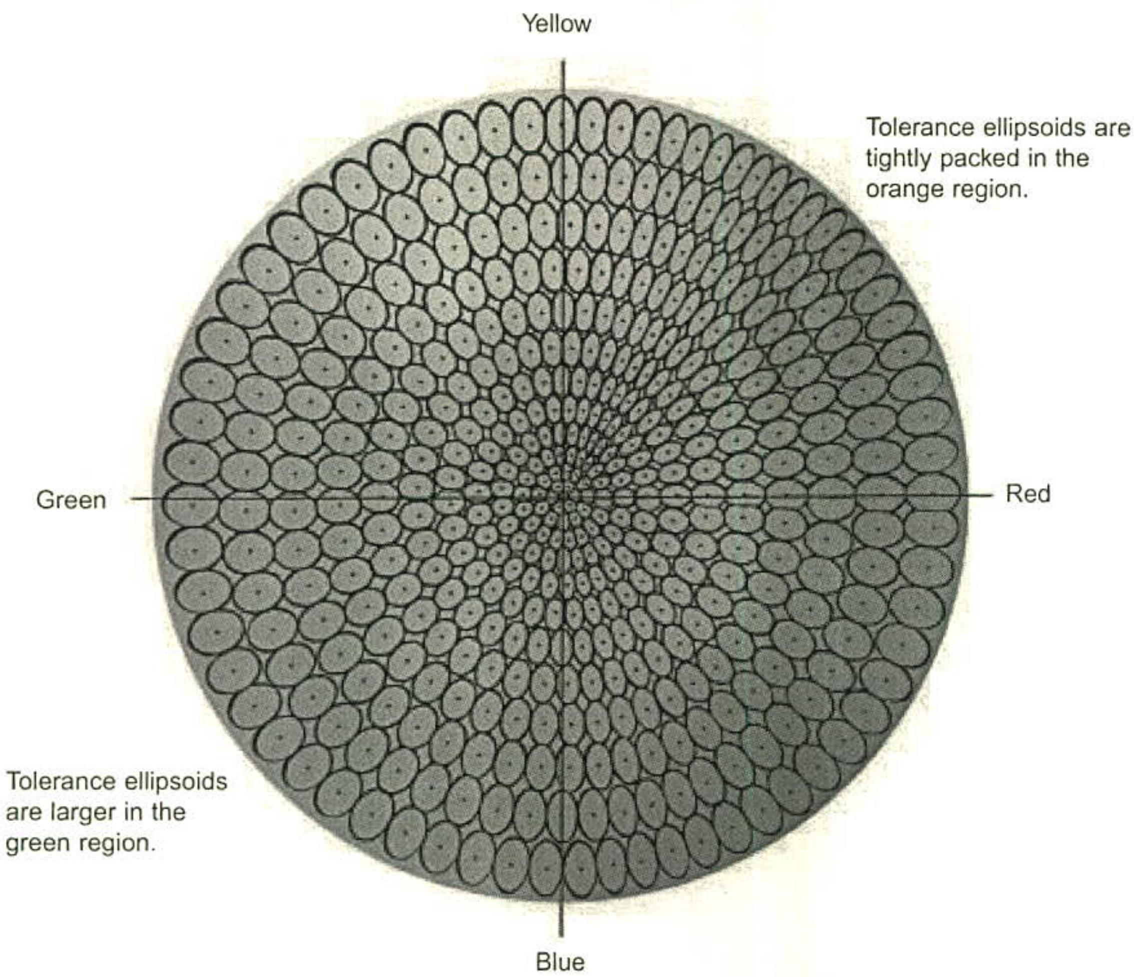

Figure 18: Tolerance ellipsoids in color space

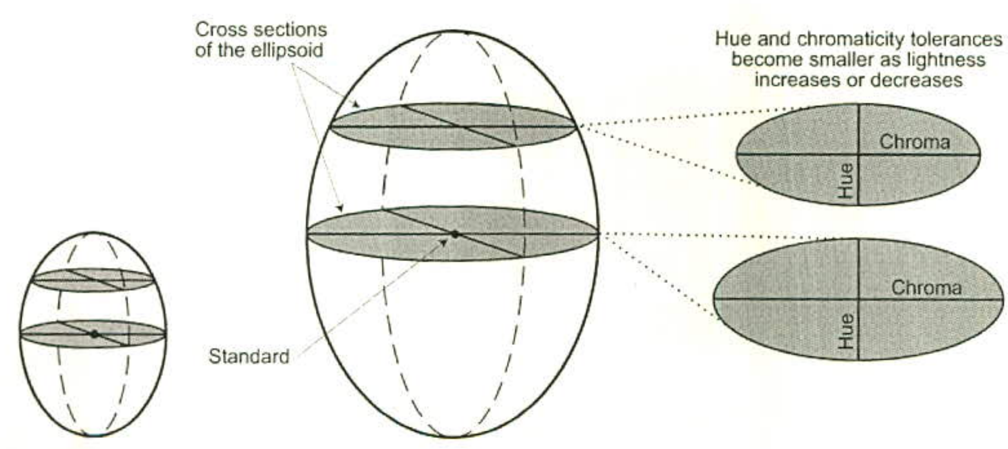

Figure 19: Commercial factor (cf) of tolerances

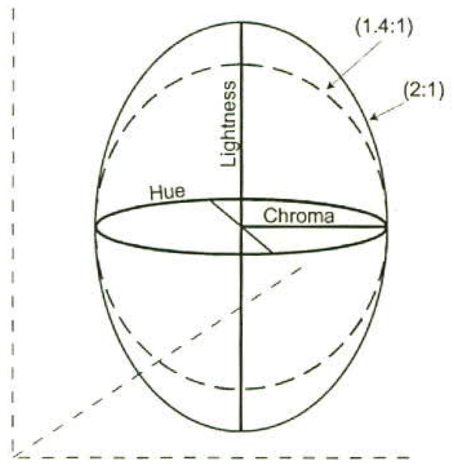

Figure 20: CMC tolerance ellipsoids

CIE94 Tolerancing

In 1994 the CIE released a new tolerance method called CIE94. Like CMC, the CIE94 tolerancing method also produces an ellipsoid. The user has control of the lightness (kL) to chroma (Kc) ratio, as well as the commercial factor (cf). These settings affect the size and shape of the ellipsoid in a manner similar to how the l:c and cf settings affect CMC.

However, while CMC is targeted for use in the textile industry, CIE94 is targeted for use in the paint and coatings industry. You should consider the type of surface being measured when choosing between these two tolerances. If the surface is textured or irregular, CMC may be the best fit. If the surface is smooth and regular, CIE94 may be the best choice.

Visual Assessment vs. Instrumental

Though no color tolerancing system is perfect, the CMC and CIE94 equations best represent color differences as our eyes see them.

Tolerance Method	% Agreement with Visual
CIELAB	75%
CIELCH	85%
CMC or CIE94	95%

Choosing the Right Tolerance

When deciding which color difference calculation to use, consider the following five rules (Billmeyer 1970 and 1979):

1. Select a single method of calculation and use it consistently.
2. Always specify exactly how the calculations are made.
3. Never attempt to convert between color differences calculated by different equations through the use of average factors.
4. Use calculated color differences only as a first approximation in setting tolerances, until they can be confirmed by visual judgments.
5. Always remember that nobody accepts or rejects color because of numbers — it is the way it looks that counts.

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Other Color Expressions

White and Yellow Indices

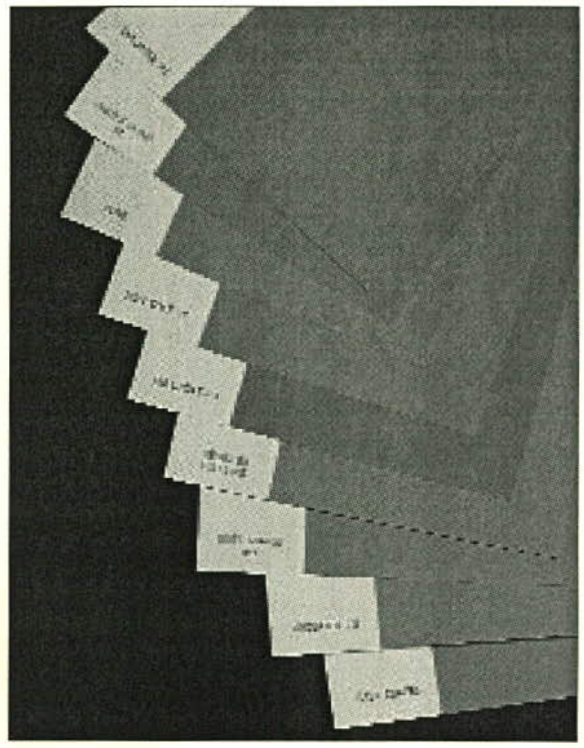
Certain industries, such as paint, textiles and paper manufacturing, evaluate their materials and products based on standards of whiteness. Typically, this whiteness index is a preference rating for how white a material should appear, be it photographic and printing paper or plastics.

In some instances, a manufacturer may want to judge the yellowness or tint of a material. This is done to determine how much that object's color departs from a preferred white toward a bluish tint.

The effect of whiteness or yellowness can be significant, for example, when printing inks or dyes on paper. A blue ink printed on a highly-rated white stock will look different than the same ink printed on newsprint or another low-rated stock.

The American Standards Test Methods (ASTM) has defined whiteness and yellowness indices. The E313 whiteness index is used for measuring near-white, opaque materials such as paper, paint and plastic. In fact, this index can be used for any material whose color appears white.

The ASTM's E313 yellowness index is used to determine the degree to which a sample's color shifts away from an ideal white. The D1925 yellowness index is used for measuring plastics.



The same blue ink looks like a different color when printed on paper of various whiteness

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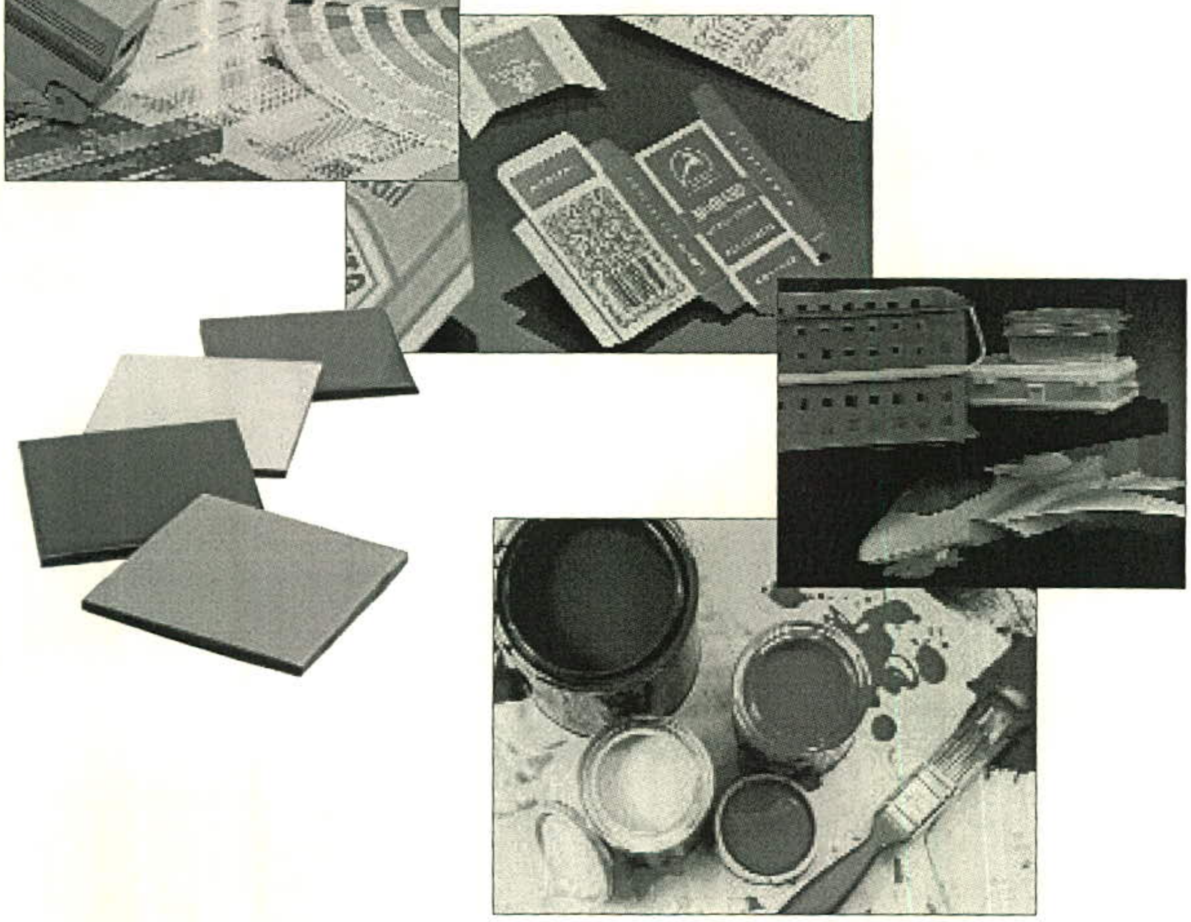
Applications

Spectrophotometry's applications are seemingly boundless. Color-matching measurements are made every day by those comparing a reproduced object to a reference point. Spectrophotometry-assisted color measurement can be useful in areas such as:

- Corporate logo standardization
- Color testing of inks
- Color control of paints
- Control of printed colors on packaging material and labels
- Color control of plastics and textiles throughout the development and manufacturing process
- Finished products like printed cans, clothing, shoes, automobile components, plastic components of all types



Interfacing X-Rite Instruments

X-Rite spectrophotometers and spectrodensitometers feature a patented remote control interface (RCI) that provides versatility in data recording. For typical record-keeping and archiving, the instruments can transmit data readings to an electronic printer for an immediate hard copy of measurements.

Beyond simple record-keeping, X-Rite instruments can output data to many desktop PCs, QC systems and other computers with serial interface capability. The computers can then display data immediately for on-site evaluation, or store the data and use it later to generate statistical process control (SPC) charts and reports.

The X-Rite RCI feature allows you to control your instrument with your computer. You can program messages and instructions to appear on the instrument's display. This makes measurement-taking easier, more accurate and more convenient.

X-Rite has designed special software packages that store, compute and display the color measurement data from our spectrophotometers.

QA-Master® 2000 is a Windows®-based color quality assurance software package designed for use with X-Rite's multi-angle, 0/45 and sphere spectrophotometers. The software utilizes client/server database technology for data storage and is 32-bit Windows NT and SQL compliant.

Powerful, user-friendly software, QA-Master 2000 offers flexible data display, which includes trending and charting in a multitude of color space options. The software has the ability to analyze density data, CMC and CIE94 color differences, DIN metamerism and CIE L*a*b* and L*C*h°.

QA-Lite® software is an expert color-control program that is inexpensive and doesn't require an advanced degree to operate. In fact, this Windows 95/98/NT-compatible program escorts you step by step through basic color checks at the click of the "Genie" button on the screen.

But just because QA-Lite software is easy to use doesn't mean it lacks power. This 32-bit program is the world's leading, full-featured quality assurance software package. With many of the same capabilities as the QA-Master 2000 software program, QA-Lite offers advanced functions not available with any other software in its price range.

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ColorMail® 2.0 is a software package that enables you to transfer color data simply and quickly. You can transfer data anywhere for access by manufacturing locations, customers, distributors, field personnel, the home office and more.

ColorMail 2.0 makes it easy to respond to customer requests quickly and accurately. You can review shipment samples before they are sent, verify a color, check inventory, quote a price on color matching or place an order from a remote location within seconds. ColorMail 2.0 operates within all e-mail and Internet communication systems with a simple, drag-and-drop utility.

Paint-Master® software is a Windows-based, advanced color-matching program that helps you eliminate costly trial-and-error from your color formulation process. Paint-Master software also helps you reduce wasted materials and disposal headaches. The program allows you to use surplus materials in new color batches because it provides formulations using available pigments or resins.

The true measures of a cost-efficient software solution are its accuracy, information clarity and overall ease of use. Paint-Master is a powerful, highly accurate formulation tool that presents color information clearly in the format most useful to you. What's more, Paint-Master software is so easy to use, you'll put it to work immediately to begin saving formulation time and money.

Plastic-Master® is a Windows-based formulation program designed for use with X-Rite color measurement spectrophotometers. The flexibility of Windows enables you to customize data displays with as much or as little information as you desire. Many of the features parallel those of Paint-Master.

Textile-Master® is a Windows-based, textile color-matching program designed for use with X-Rite color measurement spectrophotometers. This program addresses the unique dye formulation needs of exhaust dyeing, continuous dyeing (pad batch) and textile printing processes. The flexibility of Windows enables you to customize data displays with as much or as little information on the screen as you desire.

Ink-Master® is a Windows-based ink formulation system designed for use with X-Rite color measurement spectrophotometers. This program is a comprehensive laboratory package designed for the ink manufacturer or printer. It creates and controls formulation for all ink technologies, including flexographic, gravure and lithographic inks.

Glossary

absolute white – In theory, a material that perfectly reflects all light energy at every visible wavelength. In practice, a solid white with known spectral reflectance data that is used as the "reference white" for all measurements of absolute reflectance. When calibrating a spectrophotometer, often a white ceramic plaque is measured and used as the absolute white reference.

absorb/absorption – Dissipation of the energy of electromagnetic waves into other forms (e.g., heat) as a result of its interaction with matter; a decrease in directional transmittance of incident radiation, resulting in a modification or conversion of the absorbed energy.

achromatic color – A neutral color that has no hue (white, gray or black).

additive primaries – Red, green and blue light. When all three additive primaries are combined at 100% intensity, white light is produced. When these three are combined at varying intensities, a gamut of different colors is produced. Combining two primaries at 100% produces a subtractive primary, either cyan, magenta or yellow:

100% red + 100% green = yellow
100% red + 100% blue = magenta
100% green + 100% blue = cyan

See *subtractive primaries*

appearance – An object's or material's manifestation through visual attributes such as size, shape, color, texture, glossiness, transparency, opacity, etc.

artificial daylight – Term loosely applied to light sources, frequently equipped with filters, that try to reproduce the color and spectral distribution of daylight. A more specific definition of the light source is preferred.

attribute – Distinguishing characteristic of a sensation, perception or mode of appearance. Colors are often described by their attributes of hue, chroma (or saturation) and lightness.

black – In theory, the complete absorption of incident light; the absence of any reflection. In practice, any color that is close to this ideal in a relative viewing situation — i.e., a color of very low saturation and very low luminance.

brightness – The dimension of color that refers to an achromatic scale, ranging from black to white. Also called lightness, luminous reflectance or transmittance (q.v.). Because of confusion with saturation, the use of this term should be discouraged.

c* – Abbreviation for chromaticity.

chroma/chromaticity – The intensity or saturation level of a particular hue, defined as the distance of departure of a chromatic color from the neutral (gray) color with the same value. In an additive color-mixing environment, imagine mixing a neutral gray and a vivid red with the same value. Starting with the neutral gray, add small amounts of red until the vivid red color is achieved. The resulting scale obtained would represent increasing chroma. The scale begins at zero for neutral colors, but has no arbitrary end. Munsell originally established 10 as the highest chroma for a vermilion pigment and related other pigments to it. Other pigments with higher chroma were noted, but the original scale remained. The chroma scale for normal reflecting materials may extend as high as 20, and for fluorescent materials it may be as high as 30.

chromatic – Perceived as having a hue — not white, gray or black.

chromaticity coordinates (CIE) – The ratios of each of the three tristimulus values X, Y and Z in relation to the sum of the three — designated as x, y and z respectively. They are sometimes referred to as the trichromatic coefficients. When written without subscripts, they are assumed to have been calculated for illuminant C and the 2° (1931) standard observer unless specified otherwise. If they have been obtained for other illuminants or observers, a subscript describing the observer or illuminant should be used. For example, x10 and y10 are chromaticity coordinates for the 10° observer and illuminant C.

chromaticity diagram (CIE) – A two-dimensional graph of the chromaticity coordinates (x as the abscissa and y as the ordinate), which shows the spectrum locus (chromaticity coordinates of monochromatic light, 380-770nm). It has many useful properties for comparing colors of both luminous and non-luminous materials.

CIE (Commission Internationale de l'Eclairage) – The International Commission on Illumination, the primary international organization concerned with color and color measurement.

CIE 1976 L*a*b* color space – A uniform color space utilizing an Adams-Nickerson cube root formula, adopted by the CIE in 1976 for use in the measurement of small color differences.

CIE 1976 L*u*v* color space – A uniform color space adopted in 1976. Appropriate for use in additive mixing of light (e.g., color TV).

CIE chromaticity coordinates – See *chromaticity coordinates (CIE).*

CIE chromaticity diagram – See *chromaticity diagram (CIE).*

CIE daylight illuminants – See *daylight illuminants (CIE).*

CIE luminosity function (y) – See *luminosity function (CIE).*

CIE standard illuminants – See *standard illuminants (CIE).*

CIE standard observer – See *standard observer (CIE).*

CIE tristimulus values – See *tristimulus values (CIE).*

CIELAB (or CIE L*a*b*, CIE Lab) – Color space in which values L*, a* and b* are plotted using Cartesian coordinate system. Equal distances in the space approximately represent equal color differences. Value L* represents lightness; value a* represents the red/green axis; and value b* represents the yellow/blue axis. CIELAB is a popular color space for use in measuring reflective and transmissive objects.

CMC (Colour Measurement Committee of the Society of Dyes and Colourists of Great Britain) – Organization that developed and published in 1988 a more logical, ellipse-based equation based on L*C*h° color space for computing DE (see *delta E**) values as an alternative to the rectangular coordinates of the CIELAB color space.

color – One aspect of appearance; a stimulus based on visual response to light, consisting of the three dimensions of hue, saturation and lightness.

color attribute – A three-dimensional characteristic of the appearance of an object. One dimension usually defines the lightness, the other two together define the chromaticity.

color difference – The magnitude and character of the difference between two colors under specified conditions.

color-matching functions – Relative amounts of three additive primaries required to match each wavelength of light. The term is generally used to refer to the CIE standard observer color-matching functions.

color measurement – Physical measurement of light radiated, transmitted or reflected by a specimen under specified condition and mathematically transformed into standardized colorimetric terms. These terms can be correlated with visual evaluations of colors relative to one another.

color model – A color-measurement scale or system that numerically specifies the perceived attributes of color. Used in computer graphics applications and by color measurement instruments.

color order systems – Systems used to describe an orderly three-dimensional arrangement of colors. Three bases can be used for ordering colors: 1) an appearance basis (i.e., a psychological basis) in terms of hue, saturation and lightness; an example is the Munsell System; 2) an orderly additive color mixture basis (i.e., a psychophysical basis); examples are the CIE System and the Ostwald System; and 3) an orderly subtractive color mixture basis; an example is the Plochere Color System based on an orderly mixture of inks.

color space – Three-dimensional solid enclosing all possible colors. The dimensions may be described in various geometries, giving rise to various spacings within the solid.

color specification – Tristimulus values, chromaticity coordinates and luminance value, or other color-scale values, used to designate a color numerically in a specified color system.

color temperature – A measurement of the color of light radiated by a black body while it is being heated. This measurement is expressed in terms of absolute scale, or degrees Kelvin. Lower Kelvin temperatures such as 2400K are red; higher temperatures such as 9300K are blue. Neutral temperature is white, at 6504K.

color wheel – The visible spectrum's continuum of colors arranged in a circle, where complementary colors such as red and green are located directly across from each other.

colorants – Materials used to create colors — dyes, pigments, toners, waxes, phosphors.

colorimeter – An optical measurement instrument that responds to color in a manner similar to the human eye — by filtering reflected light into its dominant regions of red, green and blue.

colorimetric – Of, or relating to, values giving the amounts of three colored lights or receptors — red, green and blue.

colorist – A person skilled in the art of color matching (colorant formulation) and knowledgeable concerning the behavior of colorants in a particular material; a tinter (q.v.) (in the American usage) or a shader. The word "colorist" is of European origin.

complements – Two colors that create neutral gray when combined. On a color wheel, complements are directly opposite from each other: blue/yellow, red/green and so on.

contrast – The level of variation between light and dark areas in an image.

D65 – The CIE standard illuminant that represents a color temperature of 6504K. This is the color temperature most widely used in graphic arts industry viewing booths. See *Kelvin (K).*

daylight illuminants (CIE) – Series of illuminant spectral power distribution curves based on measurements of natural daylight and recommended by the CIE in 1965. Values are defined for the wavelength region 300 to 830nm. They are described in terms of the correlated color temperature. The most important is D65 because of the closeness of its correlated color temperature to that of illuminant C, 6774K. D75 bluer than D65 and D55 yellower than D65 are also used.

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delta (D or Δ) – A symbol used to indicate deviation or difference.

delta E*, delta e* – The total color difference computed with a color difference equation (ΔE_{ab} or ΔE_{cmc}). In color tolerancing, the symbol DE is often used to express Delta Error.

dye – A soluble colorant — as opposed to pigment, which is insoluble.

dynamic range – An instrument's range of measurable values, from the lowest amount it can detect to the highest amount it can handle.

electromagnetic spectrum – The massive band of electromagnetic waves that pass through the air in different sizes, as measured by wavelength. Different wavelengths have different properties, but most are invisible — and some completely undetectable — to human beings. Only wavelengths that are between 380 and 720 nanometers are visible, producing light. Waves outside the visible spectrum include gamma rays, x-rays, microwaves and radio waves.

emissive object – An object that emits light. Emission is usually caused by a chemical reaction, such as the burning gasses of the sun or the heated filament of a light bulb.

fluorescent lamp – A glass tube filled with mercury gas and coated on its inner surface with phosphors. When the gas is charged with an electrical current, radiation is produced. This, in turn, energizes the phosphors, causing them to glow.

gloss – An additional parameter to consider when determining a color standard, along with hue, value, chroma, the texture of a material and whether the material has metallic or pearlescent qualities. Gloss is an additional tolerance that may be specified in the Munsell Color Tolerance Set. The general rule for evaluating the gloss of a color sample is the higher the gloss unit, the darker the color sample will appear. Conversely, the lower the gloss unit, the lighter a sample will appear.

Gloss is measured in gloss units, which use the angle of measurement and the gloss value (e.g. 60˚ gloss = 29.8). A 60˚ geometry is recommended by the American Society for Testing and Materials (ASTM) D523 standard for the general evaluation of gloss.

grayscale – An achromatic scale ranging from black through a series of successively lighter grays to white. Such a series may be made up of steps that appear to be equally distant from one another (such as the Munsell Value Scale), or it may be arranged according to some other criteria such as a geometric progression based on lightness. Such scales may be used to describe the relative amount of difference between two similar colors.

hue – 1) The first element in the color-order system, defined as the attribute by which we distinguish red from green, blue from yellow, etc. Munsell defined five principal hues (red, yellow, green, blue and purple) and five intermediate hues (yellow-red, green-yellow, blue-green, purple-blue and red-purple. These 10 hues (represented by their corresponding initials R, YR, Y, GY, G, BG, B, PB, P and RP) are equally spaced around a circle divided into 100 equal visual steps, with the zero point located at the beginning of the red sector. Adjacent colors in this circle may be mixed to obtain continuous variation from one hue to another. Colors defined around the hue circle are known as chromatic colors. 2) The attribute of color by means of which a color is perceived to be red, yellow, green, blue, purple, etc. White, black and gray possess no hue.

illuminant – Mathematical description of the relative spectral power distribution of a real or imaginary light source — i.e., the relative energy emitted by a source at each wavelength in its emission spectrum. Often used synonymously with "light source" or "lamp," though such usage is not recommended.

illuminant A (CIE) – Incandescent illumination, yellow-orange in color, with a correlated color temperature of 2856K. It is defined in the wavelength range of 380 to 770nm.

illuminant C (CIE) – Tungsten illumination that simulates average dayllight, bluish in color, with a correlated color temerature of 6774K.

illuminants D (CIE) – Daylight illuminants, defined from 300 to 830nm (the UV portion 300 to 380nm being necessary to correctly describe colors that contain fluorescent dyes or pigments). They are designated as D, with a subscript to describe the correlated color temperature; D65 is the most commonly used, having a correlated color temperature of 6504K, close to that of illuminant C. They are based on actual measurements of the spectral distribution of daylight.

integrating sphere – A sphere manufactured or coated with a highly reflective material that diffuses light within it.

Kelvin (K) – Unit of measurement for color temperature. The Kelvin scale starts from absolute zero, which is -273˚ Celsius.

light – 1) Electromagnetic radiation of which a human observer is aware through the visual sensations that arise from the stimulation of the retina of the eye. This portion of the spectrum includes wavelengths from about 380 to 770nm. Thus, to speak of ultraviolet light is incorrect because the human observer cannot see radiant energy in the ultraviolet region. 2) Adjective meaning high reflectance, transmittance or level of illumination as contrasted to dark, or low level of intensity.

light source – An object that emits light or radiant energy to which the human eye is sensitive. The emission of a light source can be described by the relative amount of energy emitted at each wavelength in the visible spectrum, thus defining the source as an illuminant. The emission also may be described in terms of its correlated color temperature.

lightness – Perception by which white objects are distinguished from gray, and light-colored objects from dark-colored.

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luminosity function (y) (CIE) – A plot of the relative magnitude of the visual response as a function of wavelength from about 380 to 780nm, adopted by CIE in 1924.

metamerism – A phenomenon exhibited by a pair of colors that match under one or more sets of illuminants (be they real or calculated), but not under all illuminants.

Munsell Color System – The color identification of a specimen by its Munsell hue, value and chroma as visually estimated by comparison with the Munsell Book of Color.

nanometer (nm) – Unit of length equal to 10-9 meter (a.k.a. one billionth of a meter, or a milli-micron).

observer – The human viewer who receives a stimulus and experiences a sensation from it. In vision, the stimulus is a visual one and the sensation is an appearance.

observer, standard – See *standard observer.*

radiant energy – A form of energy consisting of the electromagnetic spectrum, which travels at 299,792 kilometers/second (186,206 miles/second) through a vacuum, and more slowly in denser media (air, water, glass, etc.). The nature of radiant energy is described by its wavelength or frequency, although it also behaves as distinct quanta ("corpuscular theory"). The various types of energy may be transformed into other forms of energy (electrical, chemical, mechanical, atomic, thermal, radiant), but the energy itself cannot be destroyed.

reflectance – The ratio of the intensity of reflected radiant flux to that of incident flux. In popular usage, it is considered the ratio of the intensity of reflected radiant energy to that reflected from a defined reference standard.

reflectance, specular – See *specular reflectance.*

reflectance, total – See *total reflectance.*

saturation – The attribute of color perception that expresses the amount of departure from a gray of the same lightness. All grays have zero saturation (ASTM). See *chroma/chromaticity.*

scattering – Diffusion or redirection of radiant energy encountering particles of different refractive index. Scattering occurs at any such interface, at the surface, or inside a medium containing particles.

spectral power distribution curve – Intensity of radiant energy as a function of wavelength, generally given in relative power terms.

spectrophotometer – Photometric device that measures spectral transmittance, spectral reflectance or relative spectral emittance.

spectrophotometric curve – A curve measured on a spectrophotometer; a graph with relative reflectance or transmittance (or absorption) as the ordinate, plotted with wavelength or frequency as the abscissa.

spectrum – Spatial arrangement of components of radiant energy in order of their wavelengths, wave number or frequency.

specular gloss – Relative luminous fractional reflectance from a surface in the mirror or specular direction. It is sometimes measured at 60° relative to a perfect mirror.

specular reflectance – Reflectance of a beam of radiant energy at an angle equal but opposite to the incident angle; the mirror-like reflectance. The magnitude of the specular reflectance on glossy materials depends on the angle and the difference in refractive indices between two media at a surface. The magnitude may be calculated from Fresnel's Law.

specular reflectance excluded (SCE) – Measurement of reflectance made in such a way that the specular reflectance is excluded from the measurement; diffuse reflectance. The exclusion may be accomplished by using 0° (perpendicular) incidence on the samples. This then reflects the specular component of the reflectance back into the instrument by use of black absorbers or light traps at the specular angle when the incident angle is not perpendicular, or in directional measurements by measuring at an angle different from the specular angle.

specular reflectance included (SCI) – Measurement of the total reflectance from a surface, including the diffuse and specular reflectances.

standard – A reference against which instrumental measurements are made.

standard illuminants (CIE) – Known spectral data established by the CIE for four different types of light sources. When using tristimulus data to describe a color, the illuminant must also be defined. These standard illuminants are used in place of actual measurements of the light source.

standard observer (CIE) – 1) A hypothetical observer having the tristimulus color-mixture data recommended in 1931 by the CIE for a 2° viewing angle. A supplementary observer for a larger angle of 10° was adopted in 1964. 2) The spectral response characteristics of the average observer defined by the CIE. Two such sets of data are defined, the 1931 data for the 2° visual field (distance viewing) and the 1964 data for the annular 10° visual field (approximately arm's length viewing). By custom, the assumption is made that if the observer is not specified, the tristimulus data has been calculated for the 1931, or 2° field observer. The use of the 1964 data should be specified.

subtractive primaries – Cyan, magenta and yellow. Theoretically, when all three subtractive primaries are combined at 100% on white paper, black is produced. When these are combined at varying intensities, a gamut of different colors is produced. Combining two primaries at 100% produces an additive primary, either red, green or blue:

100% cyan + 100% magenta = blue
100% cyan + 100% yellow = green
100% magenta + 100% yellow = red

tint – 1) *verb:* To mix white pigment with absorbing (generally chromatic) colorants. 2) *noun:* The color produced by mixing white pigment with absorbing (generally chromatic) colorants. The resulting mixture is lighter and less saturated than the color without the white added.

total reflectance – Reflectance of radiant flux reflected at all angles from the surface, thus including both diffuse and specular reflectances.

transparent – Describes a material that transmits light without diffusion or scattering.

tristimulus – Of, or consisting of, three stimuli; generally used to describe components of additive mixture required to evoke a particular color sensation.

tristimulus colorimeter – An instrument that measures tristimulus values and converts them to chromaticity components of color.

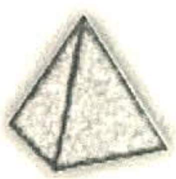
tristimulus values (CIE) – Percentages of the components in a three-color additive mixture necessary to match a color; in the CIE system, they are designated as X, Y and Z. The illuminant and standard observer color-matching functions used must be designated; if they are not, the assumption is made that the values are for the 1931 observer (2° field) and illuminant C. The values obtained depend on the method of integration used, the relationship of the nature of the sample and the instrument design used to measure the reflectance or transmittance. Tristimulus values are not, therefore, absolute values characteristic of a sample, but relative values dependent on the method used to obtain them. Approximations of CIE tristimulus values may be obtained from measurements made on a tristimulus colorimeter that gives measurements generally normalized to 100. These must then be normalized to equivalent CIE values. The filter measurements should be properly designated as R, G and B instead of X, Y and Z.

value – Indicates the degree of lightness or darkness of a color in relation to a neutral gray scale. The scale of value (or V, in the Munsell system of color notation) ranges from 0 for pure black to 10 for pure white. The value scale is neutral or without hue.

X – 1) One of the three CIE tristimulus values; the red primary. 2) Spectral color-matching functions of the CIE standard observer used for calculating the X tristimulus value. 3) One of the CIE chromaticity coordinates calculated as the fraction of the sum of the three tristimulus values attributable to the X value.

Y – 1) One of the three CIE tristimulus values, equal to the luminous reflectance or transmittance; the green primary. 2) Spectral color-matching function of the CIE standard observer used for calculating Y tristimulus value. 3) One of the CIE chromaticity coordinates calculated as the fraction of the sum of the three tristimulus values, attributable to the Y value.

Z – 1) One of the three CIE tristimulus values; the blue primary. 2) Spectral color-matching function of the CIE standard observer used for calculating the Z tristimulus value. 3) One of the CIE chromaticity coordinates calculated as the fraction of the sum of the three tristimulus values attributable to the Z primary.



Related Internet Sites

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American Society for Quality Control . . . . www.asqc.org
Association of Professional Color Imagers . . . . pmai.org/pmai/sections/apcl.htm
ASTM Technical Standards for Industry Worldwide . . . . www.astm.org
Color & Appearance Division (Society of Plastics Engineers) . . specad.org
International Color Consortium . . . . www.color.org
International Commission on Illumination (CIE), Japan . . . . www.cie.co.at/cie
International Society for Optical Engineering (SPIE) . . . . spie.org
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ISO Homepage (International Standards Organization) . . . . www.iso.ch
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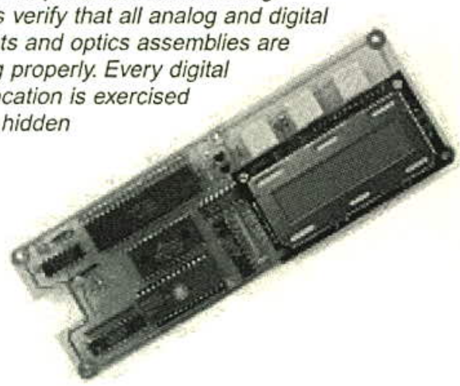

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