Requirements Governing Light Sources Used for Color Evaluation

Taiji SATO and Ikuo SATO

There are three requirements and three cautions to be employed in selecting light sources for correct evaluation of color.
Requirement [1]: The average color rendering evaluation number of the light source shall have a minimum 96, preferably close to 100 as possible. Requirement [2]: The color temperature of the light source shall be as close as possible to a color temperature of 5000-6000K of sunlight. Requirement [3]: Intensity of illumination shall be well provided. Caution [1]: The characteristics and capabilities pertaining to the three requirements shall not deteriorate as a result of aging. Caution [2]: The spectral distribution of light shall present a continuous spectrum and such spectrum shall not contain any line spectrum which represent energy in excess of 1.5 times its perimeter. Caution [3]: All of the three requirements shall be fully supported respectively and none of them should be neglected.

1. INTRODUCTION

People need some illumination light to see the shape or color of an object. The light can be provided by a wide variety of sources, including natural sunlight, fluorescent lamp, incandescent lamp, metal halide lamp, etc. which are suitable enough for people to see things, however, as anybody knows, color can be seen differently depending on the light source. Therefore, when color is discussed by the color experts, the light source is one of the most important factors which must not be disregarded.

Generally, the color of an object is most accurately seen by the natural sunlight that reaches the earth two hours before or after noon (10 a.m. to 2 p.m.) on a clear day. Every effort has been exercised to develop light sources to make them as close as possible to this natural light.

In recent years, the colors used for color printing, paints, inks, photographs, plastic materials, or design are becoming more complicated increasingly with different types of colors such as pearl, metallic and flip-flop flavors employed. As such, needs are increasing for alternative light sources to the sunlight.

This papers summarizes requirements in selecting alternative light sources to the sunlight as a result of investigations of over 2000 installations, in addition to the experiences and comments offered by color experts such as professional designers, photographers, paint ink color engineers, color inspectors, painters, art collectors and graphic artists.

2. PROCESS OF COLOR RECOGNITION

The general process of recognizing the color of an object is that the light that hits the object is reflected (transmitted) to the eye, which stimulates the RGB of the brain to recognize the color, depending on the wavelength and intensity of the reflected (transmitted) light.

The object itself does not emit colors. Colors are generated by the process: lights of certain wavelengths from many other incidental light sources that hit the object are reflected only in accordance with the spectral reflectance (transmission) characteristics of the object, and the remaining wavelengths of lights are absorbed by the object.

On the other hand, if the object reflects light of all wavelengths with the same intensity, people will sense the color of the object as "white," and if the object absorbs all wavelengths without reflection (penetration), then people will sense the color as "black."

Therefore, the light required to sense the color accurately must include wavelengths of all colors and the spectral energy must be evenly distributed throughout the visible range.

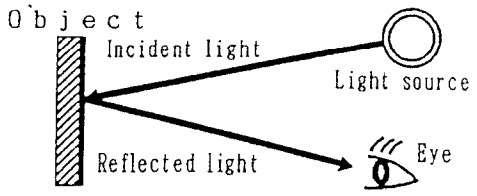

Fig. 1 Process of color recognition

The sunlight that has an evenly distributed spectral distribution is an ideal light source to see colors accurately.

3. SPECTRAL DISTRIBUTION OF DIFFERENT TYPES OF LIGHT SOURCE

The spectral distribution characteristics of the natural and artificial light sources that we use in our daily lives are generally explained as follows:

(1) Natural sunlight

The sunlight that reaches the earth has a color temperature that changes from 2400 to 6000K during the day from sunrise to sunset. The sunlight from 10:00 a.m. to 2:00 p.m. on a clear day is the most suitable for color evaluation. The light has a temperature from 5000 to 6000K with a color rendering evaluation number of 100. However, because the direct light has a high luminance, a location which is suitable for evaluation should be selected.

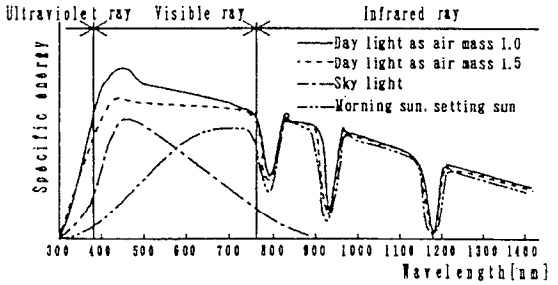

Fig. 2 Spectral distribution of natural light

(2) Northern blue sky

The blue color of the northern sky (southern sky in the southern hemisphere) occurs when the sunlight is scattered and absorbed by moisture and dust in the atmosphere. The shorter the wavelength, the larger the scattering and absorption, making the blue color more intense and the red color relatively low. This causes the color temperature to exceed 6500K, and often as high as 20000K. However, it is used as a standard light as it is relatively stable when mixed with the sunlight.

(3) Incandescent lamp

The incandescent lamp (including halogen lamp) emits light by heat radiation from a heated filament, having a continuous spectral distribution up and rightwards with a lower blue color and higher red color. For the average color rendering evaluation number, it is as high as 100 since it is close to the black body radiation but the color temperature can be as low as from 2650K to 3200K. This makes the white color more yellowish and blue color darkish. Conversely, the red color is more enhanced than it actually is.

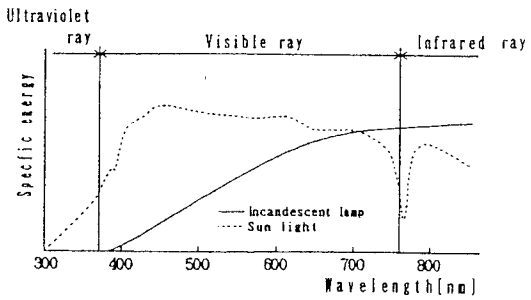

Fig. 3 Spectral distribution of incandescent lamp (example)

(4) Fluorescent lamp

The fluorescent lamp fluoresces when the phosphor coated on the inner wall of a glass tube is radiated with ultraviolet rays. Since it emits light by several fluorescent substances corresponding to RGB, there are line spectrums. There are several types of fluorescent lamp available as the color temperature changes in a range from 3500K to 6500K in accordance with the formulated balance of fluorescent substances. The spectrum changes largely in its distribution, and with a number of line spectrums, it needs careful attention when separating colors.

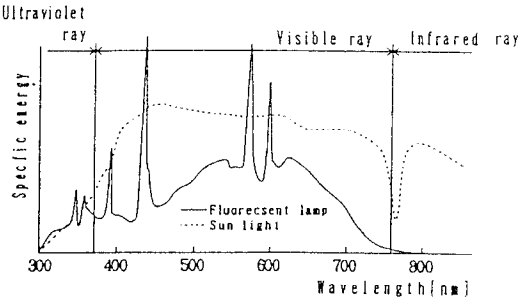

Fig. 4 Spectral distribution of high-color rendering fluorescent lamp (example)

(5) Metal halide lamp

The metal halide lamp that has several metallic vapors such as thallium, sodium, etc. in a light emission bulb, emits in accordance with the wavelengths characteristics of metallic vapors. The mercury lamp has mercury vapor in the bulb and emits by the same principle. As with the fluorescent lamp, the spectrum has also changes largely in its distribution, and with a number of line spectrums, it also needs careful attention when separating colors.

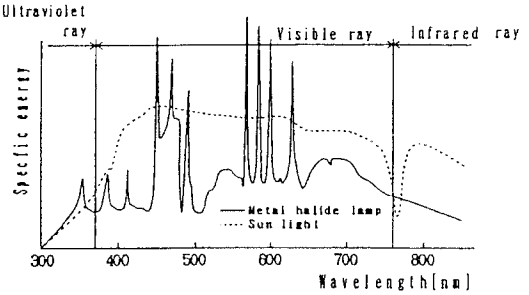

Fig.5 Spectral distribution of high-color rendering metal halide lamp (example)

(6) Artificial solar illumination lamp

The artificial solar illumination lamp uses a light source from the xenon lamp adjusted by spectral correction filters for spectral energy of each wavelength to make it closer to the spectral distribution of the sunlight in the daytime. The average color rendering evaluation number is over Ra96, having a color temperature of 5500K, and the intensity of illumination can be increased up to 100000 lux. Ultraviolet or infrared rays can be selected by properly using spectral correction filters. As it uses direct current, it has a continuous spectrum without flashing and aged deterioration to the full life of the lamp. It has the advantages that the color temperature does not change even if the intensity of light is changed.

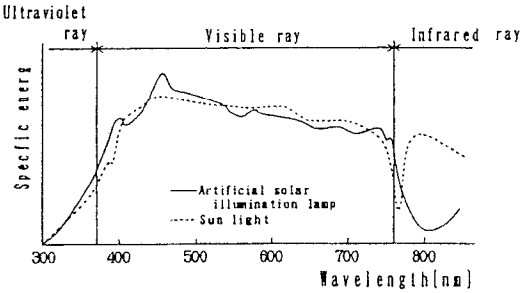

Fig.6 Spectral distribution of artificial solar illumination lamp

4. REQUIREMENTS OF LIGHT SOURCES FOR COLOR EVALUATION

There are three requirements and three cautions to be employed in selecting light sources for correct color evaluation.

Requirement [1]: The average color rendering evaluation number of the light source shall have a minimum 96, preferably as close to 100 as possible.

A continuous spectral light close to the characteristics of the black body radiation is required to render all colors accurately. The natural sunlight, artificial solar illumination lamp, the light from blue sky and incandescent lamp are light sources with best fit this requirement.

Requirement [2]: The color temperature of the light source shall be as close as possible to a color temperature of 5000-6000K of sunlight.

Requirement [3]: Intensity of illumination shall be well provided.

The intensity of light required for color evaluation is subject to the reflection (transmission) factor (brightness) of an object. The deeper colors need higher luminance, and brighter colors can be lower in luminance. Solid colors need 2000 to.6000 lux, and metallic colors need 6000 to 20000 lux. As reference information, the luminance at a north window on a clear day is about 2000 to 10000 lux.

Caution [1]: The characteristics and capabilities pertaining to the three requirements shall not deteriorate as a result of aging.

The characteristics of the light source preferably remains unchanged until the end of its life. However, it should be noted that the fluorescent lamp or metal halide lamp deteriorate by aging faster than the other light sources.

Caution [2]: The spectral distribution of light shall present a continuous spectrum and such spectrum shall not contain any line spectrums which represent energy in excess of 1.5 times its perimeter.

If there is an intense line spectrums in the spectral distribution, it causes large errors in color separation. It would be better to avoid the line spectrums.

Caution [3]: All of the three requirements shall be fully supported respectively, and none of them should be neglected.

5. SUITABILITY OF EACH LIGHT SOURCE

Suitability of each light source in terms of color evaluation is summarized in the following table. However the suitability of each of the light sources should be subject to how the accuracy of the color evaluation is defined. The table summarizes what are required in the color expert fields for evaluation of colors, including paint or ink matching, color design, paint creation, authentication or appreciation of arts or color products, with some references to actual experiences in this field.

Table Suitability of each of the light sources in relation to the three requirements and three cautions in selecting the best light source for color evaluation

Light source	Requirement 1 Color rendering	Requirement 2 Color temperature	Requirement 3 Brightness	Caution 1	Caution 2	Caution 3	Total point
Sunlight (daylight on a clear day)	◎	◎	◎	◎	◎	◎	◎
Sunlight (morning and evening light)	○	×	◎	×	◎	×	×
North sky (blue sky. light from north window)	◎	△	◎	○	◎	△	○
Light from cloudy or rainy day	○	△	△	△	◎	△	×
Incandescent lamp (including halogen lamps)	◎	×	◎	◎	◎	×	×
fluorescent lamp (normal)	×	○	△	△	×	×	×
fluorescent lamp (high-color rendition)	◎	○	△	△	×	△	×
Metal halide lamps (high-color rendition)	△	○	◎	△	×	△	×
Mercury lamps (high-color rendition)	△	○	◎	△	×	△	×
D65 fluorescent lamp (high-color rendition)	◎	○	△	△	×	△	×
Artificial solar illumination lamp	◎	◎	◎	◎	◎	◎	◎

Remarks : ◎ : Most suitable ○ : Suitable △ : Suitable on condition × : Not suitable

Ikuo SATO, Taiji SATO
Engineering Department, SERIC LTD., 1-3-903 Akashi-Cho, Chuo-Ku, Tokyo 104, Japan